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Late Cretaceous (Campanian and Maastrichtian) ammonites from Awaji Island, Southwest Japan*

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Abstract

The ammonites from the Upper Cretaceous Izumi Group in Awaji Island were studied paleontologically and biostratigraphically, and their implications in the Upper Cretaceous biostratigraphy of Japan were discussed.

Twenty species of ammonites in six families and thirteen genera are discriminated, and eighteen of them are paleontologically described, three of which, *Pachydiscus awajiensis, Patagiosites leavis* and *Anagaudryceras matsumotoi,* are new species. *Didymoceras awajiense* (YABE) is particularly redefined among others.

Based on the vertical distribution of certain characteristic species, the Izumi Group in Awaji Island is divided into five zones, i.e, the *Didymoceras awajiense* Zone, the *Pravitoceras sigmoidale* Zone, the *Pachydiscus awajiensis* Zone, the *Nostoceras hetonaiense* Zone and the *Pachydiscus* aff. *subcompressus* Zone in ascending order. The upper two zones, *N. hetonaiense* and *P.* aff. *subcompressus* Zones, can be assigned to K6b1 and K6b2 of Hokkaido respectively, and correlated with the Maastrichtian, whereas three other zones, which have not yet been recognized in Hokkaido, are probably assigned to the upper part of the Upper Campanian. The Campanian/Maastrichtian boundary in Awaji Island is tentatively drawn at the zonal boundary between the Zone of *Pachydiscus awajiensis* and that of *Nostoceras hetonaiense.*

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Introduction

The faunal provincialism in an increasing degree towards the end of Cretaceous period, in addition to the unsettled problem on the Campanian/Maastrichtian boundary in the stratotype sequences in Europe, makes international correlation of the Campanian and Maastrichtian by ammonites difficult (see JONES, 1963; HENDERSON, 1970; MATSUMOTO and MOROZUMI, 1980; HANCOCK and KENNEDY, 1981; etc.). This, however, seems to be partly ascribed to our insufficient knowledge of the ammonite succession in these stages as compared with that in the lower stages of the Upper Cretaceous, with the exception in some areas.

In Japan, many works on late Cretaceous ammonites have been successfully carried out in Hokkaido, where Japanese reference sequences of the Upper Cretaceous are exposed and a zonal scheme for them has been proposed by MATSUMOTO (1954; 1959d; 1967a; 1977b). Even in Hokkaido, however, the ammonite biostratigraphy of the Hetonaian, which is the latest stage of the Upper Cretaceous in the Japanese scale approximately correlatable with the Campanian and Maastrichtian, has not yet been made clear to our satisfaction.

On the other hand, the Izumi Group in Southwest Japan has been long known for the occurrence of a considerable number of ammonites of Hetonaian age, including such peculiar heteromorphs as *Didymoceras awajiense* (YABE) and *Pravitoceras sigmoidale* YABE. Through recent studies by MATSUMOTO and MOROZUMI (1980) and MATSUMOTO *et al.* (1980a; 1981b), in addition to the works of YABE (1901-02; 1915), KOBAYASHI (1931), MATSUMOTO (1936), MATSUMOTO and MAEDA (1951), MATSUMOTO and OBATA (1963) and OBATA and MATSUMOTO (1963), it has become clear that the ammonites from the Izumi Group play a significant role for the establishment of the Upper Cretaceous (Hetonaian) ammonite biostratigraphy in Japan, because they well supplement the evidence obtained in Hokkaido, including some species common to both Hokkaido and the Izumi belt at

several horizons as well as many others which have not yot been know from Hokkaido.

For some reasons, however, only a few species of ammonites have been hitherto described from the Izumi Group in Awaji Island. Therefore I intend, in this paper, to present the result of my study on late Cretaceous ammonites from Awaji, in order to make the ammonite succession in the Izumi Group clearer, since the strata in Awaji occupy biostratigraphically an important position within the entire Izumi Group, mediating between those in Shikoku and the Izumi Mountains.

In these years, several gentlemen in this province have attempted an enthusiastic hunting of fossils from the Izumi Group, and have obtained a large number of ammonite specimens. These collections constitute the main material for this study, in addition to the old one made by Dr. Y. MAEDA.

Acknowledgements

I express my sincere gratitude to Professor Emeritus Tatsuro MATSUMOTO of Kyushu University for his cordial guidance, useful advice, continuous encouragement during the course of this study and repeated readings of the manuscript, who furthermore let me examine some specimens under his study. Sincere thanks are also due to Professor Kametoshi KANMERA of Kyushu University for his critical reading of the manuscript.

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Notes on stratigraphy

The Izumi Group is a thick sequence of submarine deposits mainly composed of alternating beds of conglomerate, sandstone and mudstone of turbidite facies. It is distributed equatorially in a narrow belt along the Median Tectonic Line, for about 300 km, from the west of Shikoku eastward to the Izumi Mountains, across northern Shikoku and occuping the southern half of Awaji Island (Fig. 12).

The Izumi Group in Awaji Island, being over 10,000 m in integrated thickness, overlies unconformably acidic pyroclastic rocks of the Sennan Group, and shows a homoclinal structure, with the strike of ENE-WSW trend and the SE dip, in concordance with the general geologic structure of the Izumi belt that forms a northern wing of a eastward plunging synclinorium. Consequently, the basal part of the group is time transgressive, becoming younger towards the east.

As the distributional area of the Izumi Group in Awaji Island is cut into two blocks by the "Minato-Honjo Fault" (SASAI, 1986) of N-S trend, the correlation between the two is not precisely known stratigraphically. On the evidence of ammonites, however, they do not seem to be so much displaced as was estimated in the previous works (SASAI, 1936; ICHIKAWA, 1961). The Median Tectonic Line grazes the southern extremity of the island (KANAORI *et al.*, 1982), where the geologic structure of the Izumi Group is somewhat complicated.

Table 1. Scheme of stratigraphic divisions of the Izumi Group in Awaji Island.

Sasai, 1936	Tanaka *et al.*, 1952	Ichikawa, 1961			This paper	
Nada sandstone and conglomerate	Shimonada white sandst. Shimonada fine sandy siltstone	Up.subg.		Shimonada white sandst. Shimonada fine sandy siltstone	Shimonada Form.	
	Nada sandstone and conglomerate	Middle subgroup		Nada Formation		Nada Formation
Kita-ama sandstone	Kita-ama sandstone and shale			Kita-ama Formation		Kita-ama Formation
Shichi shale	Shichi shale	Lower subgroup	Anaga Form.	Shichi shale		Anaga Formation
Yoroizaki sandstone	Yoroizaki sandstone			Yoroizaki conglomerate		
Minato shale	Minato shale		Seidan F.	Minato shale		Seidan Form.
Tsui basal conglomerate	Tsui basal conglomerate			Tsui conglomerate		

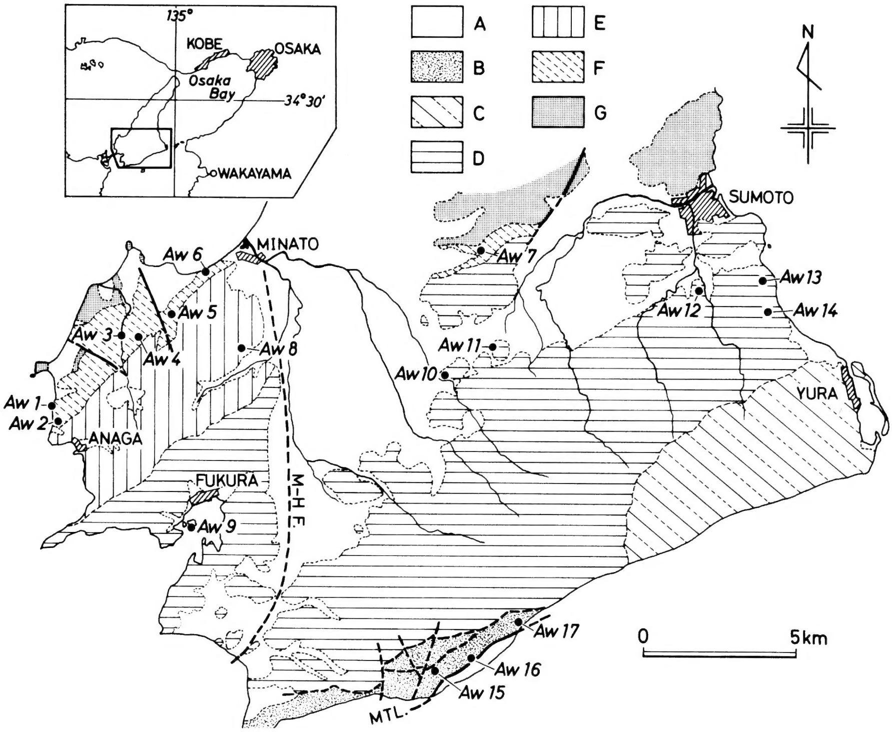

Fig. 1. Geological map of the Izumi Group in Awaji Island showing ammonite localities (Aw1-17).
A: Quaternary and Tertiary deposits, B-F: Izumi Group (B: Shimonada Formation, C: Nada Formation, D: Kita-ama Formation, E: Anaga Formation, F: Seidan Formation), G: Basement (granites and pyroclastics). M-H F.: Minato-Honjo Fault, MTL.: Median Tectonic Line. Geological map adopted from ICHIKAWA (1961) and GOTO and MIYATA (1984).

After the pioneering studies by HARADA (1890), SUZUKI (1897), and YEHARA (1921; 1925), the outline of the stratigraphy of the Izumi Group in Awaji Island was presented by SASAI (1936). Afterward some revision was made especially for the upper part of the group by TANAKA *et al.,* (1952). Summing them up, ICHIKAWA (1961) grouped a number of members into three subgroups including four formations. In this paper, I generally followed ICHIKAWA (1961) with some revision, and divided the group into five formations, i.e. the Seidan, Anaga, Kita-ama, Nada and Shimonada Formations in ascending order, as shown in Table 1. and Fig. 1

The Seidan Formation represents a northern marginal facies of the group, and consists of diachronous basal conglomerate and conformably following, rather massive mudstone. The well known, fossiliferous "Minato Shale" is the upper member of this formation in the western block, and probably represents a neritic shelf facies.

The Anaga, Kita-ama and Nada Formations constitute the main body of the group, being composed of alternating beds of sandstone or conglomeratic sandstone and

mudstone of turbidite facies. The fossiliferous "Shichi Shale" is also the upper member of the Anaga Formation. The Kita-ama Formation, which is composed of thickly bedded alternation of sandstone and mudstone in the main part, especially shows remarkable lithofacies changes. It generally tends to grade northeastward into mudstone predominant alternation with interbeds of thick mudstone, and then further northeastward into alternating beds of conglomeratic sandstone and mudstone. The muddy belt extending from the south of Sumoto City to the west, which is also somewhat fossiliferous, is interpreted to represent a distal facies of the main turbidite beds of the Kita-ama Formation, although it has been correlated with the "Shichi Shale" (SASAI, 1936; ICHIKAWA, 1961).

The Shimonada Formation shows a narrow distribution along the southwestern margin of the island, being separated from the main part of the group by a fault of E-W trend. Therefore, its stratigraphic position is not precisely known, but it appears to be synchronous with part of the Kita-ama and/or Nada Formations from the contained ammonites.

Ammonite faunas of Awaji Island

1. Previous works

Although fairly numerous ammonites occur in the Izumi Group of Awaji Island, only a few species have been fully described.

YABE (1901-02; 1915) described four ammonite species from Awaji, i.e. *Hamites* (*Anisoceras*) *awajiensis* YABE, *Pravitoceras sigmoidale* YABE, *Turrilites* (*Hyphantoceras*) *oshimai* YABE var. and *Turrilites* (*Bostrychoceras*) *otsukai* YABE, the former two of which were new. However, SASAI (1936, p. 598-599) pointed out in his stratigraphic paper that YABE (1915)'s specimens of *T.* (*H.*) *oshimai* and *T.* (*B.*) *otsukai* represented different portions of the same species as *H.* (*A.*) *awajiensis*. He called it *Bostrychoceras awajiense* (YABE), and illustrated a fairly well preserved specimen. This species is currently treated as *Didymoceras awajiense* (YABE), although it needs revision as has been pointed out by MATSUMOTO (1977a, p. 323) and MATSUMOTO *et al.* (1981b, p. 175).

Afterwards, MATSUMOTO and MAEDA (1951) described a pachydiscid ammonite and assigned it provisionally to an then unestablished species, *Pachydiscus subcompressus* MATSUMOTO, 1954. OBATA and MATSUMOTO (*in* MATSUMOTO and OBATA, 1963) described *B. inornatus* MEEK in their monograph of Baculitidae of Japan. Moreover some ammonites were only listed without description and illustration by MATSUMOTO (1954), ICHIKAWA and MAEDA (1960), ICHIKAWA (1961) and MATSUMOTO (1978).

Thus, the hitherto described ammonites from Awaji Island are very few. One of the reasons will be attributed to poor preservation of previously treated specimens. Careful examination of well preserved specimens are needed.

Recently, *Pravitoceras sigmoidale* YABE was redescribed in detail by MATSUMOTO *et*

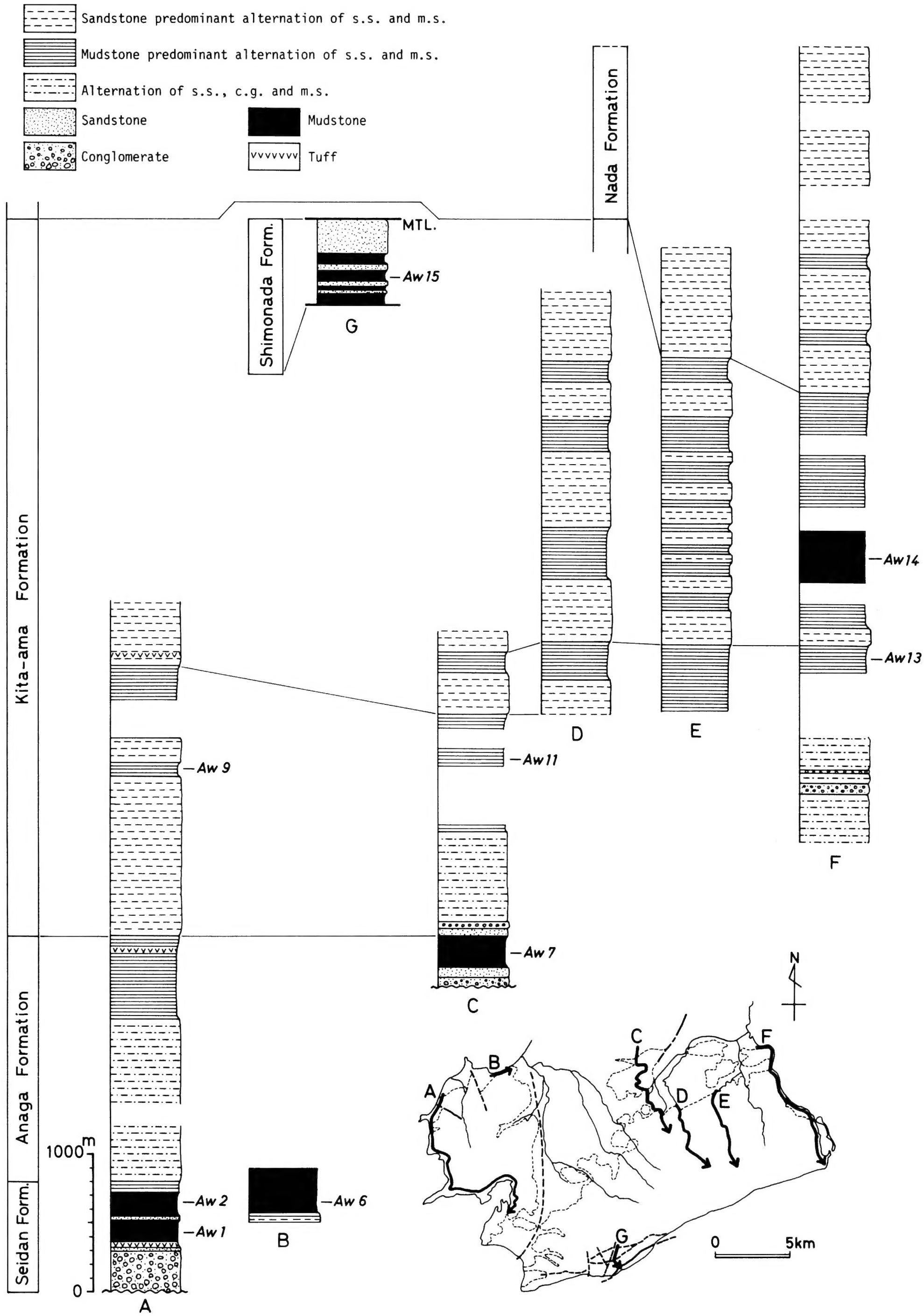

Fig. 2. Generalized columnar sections of the Izumi Group in Awaji Island.
Aw1-15 indicate the stratigraphic positions of ammonite localities. MTL.: Median Tectonic Line.

al. (1981b), based on fairly well preserved specimens of subsequent collections as well as the types described by YABE (1902; 1915). For other species, however, better materials are wanted.

2. Ammonite localities and species

Seventeen ammonite localities (locs. Aw1-17) are recognized in the Izumi Group of Awaji Island, as shown in Fig. 1. Some nearby exposures of the same horizon are included in one locality. These localities are mostly distributed in the northern and southern marginal parts of the distributional area of the Izumi Group, i.e. in the Seidan Formation (locs. Aw1-7), in the distal parts of the turbidite beds of the Anaga and Kita-ama Formations (locs. Aw8, 10-14) and in the Shimonada Formation (locs. Aw15-17). Only a few ammonites are known to occur in the main part of turbidite facies.

The location, ammonite species and important fossils other than ammonites of each locality are as follows (the species with asterisk are not described in the systematic part of this study):

Loc. Aw1 (Kiba): a wave cut bench about 500 m south of Kiba, Seidan-cho, Mihara-gun; "Minato Shale" of the Seidan Formation.

The fossils occur mostly in calcareous nodules in fine sandy siltstone. Recently well preserved specimens of *Didymoceras* were collected by Mr. SATO and his cooperators, by drawing up nodules from a submarine exposure.

Ammonite species:

Hypophylloceras (*Neophylloceras*) *hetonaiense* MATSUMOTO
Pachydiscus (?) sp. (immature)*
Patagiosites laevis MOROZUMI, n. sp.
Gaudryceras sp. aff. *G. striatum* (JIMBO)
Didymoceras awajiense (YABE)

Loc. Aw2 (Minakuchi): a wave cut bench and a nearby road cut cliff at Minakuchi, Seidan-cho, about 400 m south of loc. Aw1; upper part of the "Minato Shale", Seidan Formation.

The fossils occur in sandy siltstone with some interbeds of sandstone. "*Anisomyon*" cf. *problematicus* (NAGAO and OTATUME) accompanies the ammonites.

Ammonite species:

Pravitoceras sigmoidale YABE
Solenoceras (*Solenoceras*) sp. cf. *S.* (*S.*) *texanum* (SCHMARD)

The locations of loc. Aw1 and loc. Aw2 are indicated collectively as Anaga in the previous papers (e.g. YABE, 1915; MATSUMOTO *et al.*, 1981b). Anaga is indeed a regional name including locs. Aw1 and Aw2, but reminds us the street of Anaga, about 1 km southeast of loc. Aw2. Therefore I use, in this paper, Kiba and Minakuchi for the locations of loc. Aw1 and loc. Aw2 respectively to indicate them more definitely.

Loc. Aw3 (Nakano): a river bed of the Tsui-gawa River and a nearby cliff at Nakano, about 2 km southwest of Tsui, Seidan-cho; "Minato Shale" of the Seidan Formation. The fossils occur mostly in calcareous nodules.

Ammonite species:

Didymoceras awajiense (YABE)

Loc. Aw4 (Nakano): an exposure about 500 m southeast of loc. Aw3; "Minato Shale". This locality is merely indicated as the locality record of the specimens of *Pravitoceras sigmoidale* YABE, NSM. PM7385 and others (MATSUMOTO *et al.*, 1981b, p. 174).

Loc. Aw5 (Uchihara): some exposures on a hill at Uchihara, about 1.5 km southeast of Tsui, Seidan-cho; mudstone predominant alternation of the "Minato Shale". Several fragmentary specimens of *Pravitoceras sigmoidale* YABE have been collected.

Loc. Aw6 (Minato): a large cliff along the coastal road, about 1.5 km southwest from the street of Minato, Seidan-cho; massive mudstone of the "Minato Shale".

The ammonites occur mostly in calcareous nodules within a limited horizon of about 10 m thickness. Some specimens also came from the alternating beds of mudstone and sandstone just below the above-mentioned unit.

Ammonite species:

Pravitoceras sigmoidale YABE

Solenoceras (*Oxybeloceras*) sp. aff. *S.* (*O.*) *humei* (DOUVILLÉ)

Loc. Aw7 (Nagata): several exposures about 1.5 km east of Nagata, Midori-cho, Mihara-gun; fine sandy siltstone member of the Seidan Formation.

The horizon of this locality seems to be fairly higher than the "Minato Shale" in the west, probably being of the same horizon as the "Shichi Shale" of the Anaga Formation. But I include this member in the Seidan Formation, because it has a nature of the northern marginal facies, lying just above the basal conglomerate which is also diachronous. Some materials of *Baculites inornatus* MEEK described by OBATA and MATSUMOTO (1963) came from this locality.

Recently, on the occasion of constructing a public athletic ground in the spring of 1983, many specimens of *Pachydiscus* were collected along with *"Anisomyon" problematicus* (NAGAO and OTATUME), a pateliform gastropod.

Ammonite species:

Hypophylloceras (*Neophylloceras*) sp. aff. *H.* (*N.*) *mikobokense* (COLLIGNON)

Pachydiscus (*Pachydiscus*) *awajiensis* MOROZUMI, n. sp.

Baculites inornatus MEEK

Loc. Aw8 (Hanzanji): several exposures around Hanzanji of Shichi, Seidan-cho; "Shichi Shale" of the Anaga Formation.

The fossils occur in mudstone beds of mudstone predominant alternation facies. Most specimens from this locality have occured as the fragmentary internal moulds.

Ammonite species:

Pachydiscus (*Pachydiscus*) sp. cf. *P.* (*P.*) *awajiensis* MOROZUMI

Pachydiscus (*P.*) sp. aff. *P.* (*P.*) *awajiensis* MOROZUMI

Loc. Aw9 (Kemuri-jima): a wave cut bench of a small island of Kemuri-jima in the Fukura Bay, about 1 km southwest off Fukura, Nandan-cho; alternating sandstone and mudstone of the Kita-ama Formation.

Only one internal mould of *Pachydiscus* (*P.*) sp.*, OMNH. M2189, was found by Dr. MAEDA from a mudstone bed in the turbidite facies.

Locs. Aw10 (Okubo) and Aw11 (Tokuhara): These two localities are merely based on locality records of the specimens of *Baculites inornatus* MEEK described by OBATA and MATSUMOTO (1963). Both localities are in a muddy distal facies of the Kita-ama Formation (Fig. 1), although OBATA and MATSUMOTO (1963) placed them in the upper part of the "Shichi Shale".

Loc. Aw12 (Chikusa): a road cut cliff at Chikusa in Sumoto City, about 3 km south of the street of Sumoto; mudstone with thin sandstone layers, a distal facies of the turbidite beds of the Kita-ama Formation.

Ammonite species:

Nostoceras sp. cf. *N. hetonaiense* MATSUMOTO

Nostoceras sp. ? *

Loc. Aw13 (Kake-ooji): a large cliff near the headland of Kake-ooji, about 3 km southeast of the street of Sumoto City; mudstone predominant alternation of the Kita-ama Formation. *Inoceramus* (*Endocostea*) *shikotanensis* NAGAO and MATSUMOTO was found from this locality.

Ammonite species:

Nostoceras sp. cf. *N. hetonaiense* MATSUMOTO

Loc. Aw14 (Mitsugawa): a quarry about 500 m south of Mitsugawa, Sumoto City, where mudstone is being excavated as raw materials for the cement industry; a distal facies of the main turbidite beds of the Kita-ama Formation.

Inoceramus (*Endocostea*) *shikotanensis* NAGAO and MATSUMOTO, *"Anisomyon" problematicus* (NAGAO and OTATUME) and *Eutrephoceras* sp. were found from this locality.

Ammonite species:

Nostoceras hetonaiense MATSUMOTO

Loc. Aw15 (Haraikawa): several exposures along a stream about 500 m above its mouth at Haraikawa of Nada, Nandan-cho; fine sandy, somewhat calcareous siltstone of the Shimonada Formation. Fairly numerous ammonites of relatively good preservation, accompanied by *"Inoceramus" awajiensis* MATSUMOTO, were collected by Dr. MAEDA and then by Drs. ICHIKAWA and MAEDA. These exposures are now under the detritus by constructing several dams in these years.

Table 2. List of ammonites from the Izumi Group in Awaji Island.

Localities (Aw1-17) / Species	Seidan Formation							A.F.	Kita-ama Formation						Shimonada F.		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Hypophylloceras (Neophylloceras) hetonaiense Matsumoto	●														○		
2. H. (N.) aff. mikobokense (Collignon)							●										
3. Pachydiscus (Pachydiscus) awajiensis Morozumi, n. sp.							○										
3'. P. (P.) cf. awajiensis Morozumi								○									
4. P. (P.) aff. awajiensis Morozumi								●									
5. P. (P.) aff. subcompressus Matsumoto																●	
6. P. (P.) sp. *									●								
7. Patagiosites laevis Morozumi, n. sp.	●																
8. Gaudryceras izumiense Matsumoto and Morozumi																	●
9. G. aff. striatum (Jimbo)	●																
10. Vertebrites (?) cf. kayei (Forbes)															●		
11. Anagaudryceras matsumotoi Morozumi, n. sp.															●		
12. Zelandites cf. varuna (Forbes)															●		
13. Saghalinites (?) sp.															●		
14. Solenoceras (Solenoceras) cf. texanum (Shumard)		○															
15. S. (Oxybeloceras) aff. humei (Douvillé)						●											
16. Didymoceras awajiense (Yabe)	○		○														
17. Pravitoceras sigmoidale Yabe		○		○	○	○											
18. Nostoceras hetonaiense Matsumoto														○			
18'. N. cf. hetonaiense Matsumoto												○	●				
19. N. sp. *												●					
20. Baculites inornatus Meek							●			○	○						

○: common (more than 3 specimens), ●: rare (1 or 2 specimens), *: undescribed in this paper
A.F.: Anaga Formation

Ammonite species:

Hypophylloceras (*Neophylloceras*) *hetonaiense* MATSUMOTO
Vertebrites (?) sp. cf. *V. kayei* (FORBES)
Anagaudryceras matsumotoi MOROZUMI, n. sp.
Zelandites sp. cf. *Z. varuna* (FORBES)
Saghalinites (?) sp.

Loc. Aw16 (Yamamoto): the mouth of a stream at Yamamoto of Nada, Nandan-cho. One specimen of *Pachydiscus* (*P.*) sp. aff. *P.* (*P.*) *subcompressus* MATSUMOTO, which was described by MATSUMOTO and MAEDA (1951) as *P. subcompressus,* was found by Dr. MAEDA from a floated nodule, probably derived from part of the Shimonada Formation.

Loc. Aw17 (Kuroiwa): the mouth of a stream about 300 m southwest of Kuroiwa of Nada, Nandan-cho.
One specimen of *Gaudryceras izumiense* MATSUMOTO and MOROZUMI was found by Mr. TANI from a floated nodule, probably derived from the Shimonada Formation.

The ammonite species found from the Izumi Group in Awaji Island are listed in Table 2. Of the 20 species 13 belong to the family Phylloceratidae, Pachydiscidae, Gaudryceratidae and Tetragonitidae, whereas the rest 7 are heteromorpha of the Nostoceratidae

and Baculitidae.

Most of the ammonites occur in fine sandy siltstones which are referable to a neritic facies of moderate depth. The elements of the ammonite faunas are also of outer neritic biofacies, as is suggested from the sedimentary facies.

3. Faunal zones

Fig. 3 shows the vertical distribution of ammonite localities, representative species at each horizon and the proposed ammonite biozones. The horizons of some important species other than ammonites, such as inocerami and patelliform gastropod, are also indicated. As the ammonites have been found from rather sporadical localities of restricted horizons and the faunas of given horizons differ considerably from each other, the vertical range of respective species can not be defined exactly. But I tentatively divided the group into five biozones on the basis of occurrences of some characteristic species, although the boundary of them are drawn rather artificially. These zones may belong to the concept of "local range zone".

a) *Didymoceras awajiense* Zone

The lower part of the Seidan Formation composes this zone. The base of this zone, defined by the base datum of *D. awajiense*, is not known in Awaji Island because of the

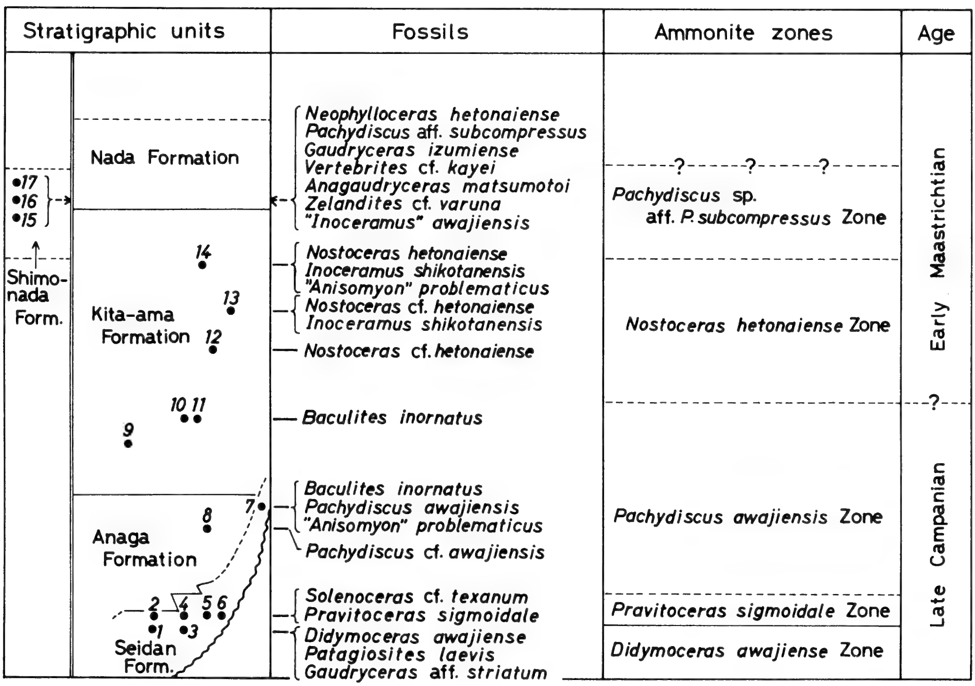

Fig. 3. Schematic columnar section showing characteristic fossils from each locality and proposed ammonite zones.

lack of exposures.

Patagiosites laevis and *Gaudryceras* aff. *striatum* are also found from this zone.

b) *Pravitoceras sigmoidale* Zone

Only a thin body of strata, the uppermost part of the Seidan Formation in the western block, constitutes this zone.

P. sigmoidale was probably derived from *Didymoceras awajiense* as has been suggested by MATSUMOTO *et al.*, (1981b, p. 175), and has a short vertical range. Therefore the base of this zone should be defined as the evolutionary base of *P. sigmoidale*, and is practically settled to the midway between the two horizons of *D. awajiense* and *P. sigmoidale*. The evidence of concurrence of the two species is insufficient, but *D. awajiense* may occur in the restricted lower part of this zone. There exists a lack of exposures of about 50 m or so in thickness between the horizons of the two species.

Solenoceras (*Oxybeloceras*) aff. *humei* and *Solenoceras* (*S.*) cf. *texanum* accompany *P. sigmoidale.*

c) *Pachydiscus awajiensis* Zone

A part of the Seidan Formation distributed in Midori-cho, the Anaga Formation and probably the lower part of the Kita-ama Formation compose this zone. The base of this zone is tentatively drawn somewhere between the local range of *Pravitoceras sigmoidale* and that of *Pachydiscus awajiensis.*

Hypophylloceras (*Neophylloceras*) aff. *mikobokense, Pachydiscus* (*P.*) aff. *awajiensis* and *Baculites inornatus* occur in this zone. *P.* (*P.*) *awajiensis* is also accompanied by *"Anisomyon" problematicus.*

d) *Nostoceras hetonaiense* Zone

This zone is represented by the upper part of the Kita-ama Formation. The base of this zone is tentatively drawn between the local range of *Baculites inornatus* and that of *Nostoceras hetonaiense*. The top of this zone is not well defined, because the overlying Nada Formation has yielded no ammonite.

Inoceramus (*Endocostea*) *shikotanensis* and *"Anisomyon" problematicus* accompany *N. hetonaiense* in this zone.

e) *Pachydiscus* aff. *subcompressus* Zone

This zone is composed of the Shimonada Formation, and characterized by the concurrence of *Hypophylloceras* (*Neophylloceras*) *hetonaiense, Pachydiscus* (*P.*) aff. *subcompressus, Gaudryceras izumiense, Vertebrites* (?) cf. *kayei, Anagaudryceras matsumotoi, Zelandites* cf. *varuna* and *Saghalinites* (?) sp.

As the Shimonada Formation is cut by a fault from the main body of the group, both the base and the top of this zone are not defined. However this zone probably represents a zone overlying the *Nostoceras hetonaiense* Zone.

Paleontological descriptions

The following abbreviations are used to indicate the repositories of the examined specimens in the present study:
GH: Department of Geology and Mineralogy, Hiroshima University
GK: Department of Geology, Kyushu University
IGPS: Institute of Geology and Paleontology, Tohoku University
KU: Department of Geology and Mineralogy, Kyoto University
NSM: Department of Geology, National Science Museum
OCU: Department of Geosciences, Osaka City University
OMNH: Osaka Museum of Natural History, THS: Tenri High School
UMUT: University Museum, the University of Tokyo

Private collections are recorded with the initials of the possessors:
JM: Jun-ichi MIYAMOTO, KI: Kazutoyo ICHIMICHI, KS: Kazuhito SAKAKIBARA, MS: Masahiro SATO, MT: Masanori TANI, SN: Shigeki NANKO, TN: Takuji NISHIOKA

The measurements are in mm.

Family Phylloceratidae ZITTEL, 1884

Genus *Hypophylloceras* SALFELD, 1924

Subgenus *Neophylloceras* SHIMIZU, 1934

Type species: *Ammonites* (*Scaphites*?) *ramosus* MEEK, 1858 (original designation).

Discussion: *Neophylloceras* was established by SHIMIZU (*in* SHIMIZU and OBATA, 1934), being separated from *Phylloceras* SUESS on account of the considerable difference in the suture. But WRIGHT (*in* MOORE [ed.], 1957, p. L189) and WIEDMANN (1962) synonymized *Neophylloceras* with *Hypophylloceras* SALFELD, which was furthermore regarded as a subgenus of *Phylloceras* by WIEDMANN (1964). This was followed by KENNEDY and KLINGER (1977).

On the other hand, MATSUMOTO (1959a, p. 57) and PACKARD (1960, p. 426), who treated *Neophylloceras* as a distinct genus, illustrated the sutures of *Hypophylloceras onoense* (STANTON), the type species of *Hypophylloceras*, and showed clearly that the suture of *Hypophylloceras* is less finely incised than that of *Neophylloceras* and has much better developed phylloid terminations. This sutural distinction between the two was also accepted to be a sufficient criterion for their separation at generic level by JONES (1963), HENDERSON (1970) and MATSUMOTO and MIYAUCHI (1984).

Anyhow, it appears significant to separate *Neophylloceras* from *Hypophylloceras* at some taxonomic level, though MATSUMOTO (1959a, p. 56) pointed out the existence of species which shows a somewhat intermediate suture. I here follow BIRKELUND (1965) and MATSUMOTO and MOROZUMI (1980), and treat *Neophylloceras* as a subgenus of *Hypophyl-*

loceras.

Hypophylloceras (*Neophylloceras*) *hetonaiense* (MATSUMOTO)
Pl. 1, figs. 1-5

1942. *Neophylloceras hetonaiense* MATSUMOTO, *Proc. Imp. Acad. Japan* 18 (10): 675; text-fig. 1.
1953. *Neophylloceras hetonaiense* MATSUMOTO: SPATH, *Falkland Isl. Depend. Surv., Sci. Rep.* (3): 5; pl. 1, fig. 2.
1959. *Neophylloceras hetonaiense* MATSUMOTO: MATSUMOTO, *Mem. Fac. Sci., Kyushu Univ., Ser. D* (*Geol.*), Spec. Vol. 1: 5; pl. 3, fig. 1.
1963. *Neophylloceras hetonaiense* MATSUMOTO: JONES, *U. S. Geol. Surv. Prof. Pap.* 432: 23; pl. 6, figs. 9-10; pl. 7, figs. 1-5; text-fig. 12.
1980. *Hypophylloceras* (*Neophylloceras*) sp. cf. *H.* (*N.*) *hetonaiense* (MATSUMOTO): MATSUMOTO and MOROZUMI, *Bull. Osaka Mus. Nat. Hist.* (33): 6; pl. 1, figs. 1-4.

Lectotype: GK. H3801a, designated by MATSUMOTO (1956b), from loc. H12b, Lower Sandy Siltstone of the Hakobuchi Group, Tomiuchi area, central Hokkaido.

Material: Eleven specimens; GK. H6884-6886, GK. H6888-6893 and OCU. MM343, all of which were collected by Y. MAEDA from loc. Aw15 (Haraikawa); OMNH. M2208, coll. by M. SATO from loc. Aw1 (Kiba), is also referable to this species.

Measurements:

Specimen		D	B	H	B/H	U (%)
GK. H6884		24.2	7.8	14.1	0.55	2.0 (8.3)
GK. H6885		33.2	9.6	19.5	0.49	2.3 (6.9)
GK. H6886		17.4	6.4	9.7	0.66	1.3 (7.5)
GK. H6888		40.4	11.8	23.3	0.51	2.5 (6.2)
〃	(−180°)	24.1	7.9	13.4	0.59	2.1 (8.7)
GK. H6890		20.5	6.5	11.7	0.56	2.0 (9.8)
〃	(−90°)	15.2	5.8	8.3	0.70	1.7 (11.2)
GK. H6891		10.9	4.3	5.6	0.77	1.3 (11.9)
GK. H6892		5.3	—	2.7	—	0.9 (17.0)
GK. H6893		25.3	8.4	14.3	0.59	1.9 (7.5)
OMNH. M2208		27.6	—	15.3	—	2.3 (8.3)

Description: The shells of the examined specimens are small, less than 40 mm in diameter, but as the body-chambers are not preserved completely in almost all of them, the entire shells would have been still larger.

The shell is very involute with a small pit-like umbilicus, which decreases its proportion to the shell diameter as the shell grows. The whorl is fairly compressed and compressed elliptical in section, with the maximum breadth at mid-flank, from where the flank inclines gradually toward umbilicus and also toward the narrowly arched venter. The whorl becomes much more compressed with the shell growth due to a papid increase in shell height.

The shell surface is ornamented by fine, simple and dense striae which are more

pronounced on the upper half of the flank than on the lower half. They are rather flexuous in the early growth stage, inclining backward near the umbilicus, forming a forward convex curve near the mid-flank and then running almost radially on the upper third of the flank. But in the later growth stage, they are slightly flexuous and pass in a prorsiradiate direction on the upper half of the flank. Bullate umbilical ribs develop on the lower half of the flank of small shells having a diameter less than 30 mm; they are 9 or 10 in number per whorl.

The suture is not completely traceable for the present materials, but is deeply and finely incised and of the same as that figured by JONES (1963, p. 23).

Discussion: The above observation agrees well with the diagnosis of *Neophylloceras hetonaiense* MATSUMOTO (MATSUMOTO, 1942c, p. 675; 1959c, p. 5). Small shell size of the present materials also coincides with that of the examples from the type locality of this species. It is interesting that larger specimens referable to this species alone are known from the Izumi Group (Azenotani Formation) of the Izumi Mountains (MATSUMOTO and MOROZUMI, 1980), in contrast with small presnt materials. This seems to be a reflection of some differences in sedimentary environments between the Azenotani and the Shimonada Formations.

MATSUMOTO (1959c, p. 6) mentioned that the species ranged from the Campanian to the Maastrichtian in Japan, and that the variety characterized by well defined bullate ribs were known in the Maastrichtian (Upper Hetonaian). This kind of umbilical ribs are discernible on most present materials, even on OMNH. M2208 from the *Didymoceras awajiense* Zone, probable upper part of the Upper Campanian.

Occurrence: In Awaji Island, this species occur abundantly in the calcareous siltstone of the Shimonada Formation with fairly good preservation, associated characteristically with *"Inoceramus" awajiensis* MATSUMOTO. This species is rarely found from the "Minato Shale" of the Seidan Formation.

Hypophylloceras (*Neophylloceras*) sp.
aff. *H.* (*N.*) *mikobokense* (COLLIGNON)
Pl. 1, fig. 6

cf. 1956. *Epiphylloceras mikobokense* COLLIGNON, *Ann. Géol. Serv. Mines, Madagascar* 23: 24; pl. 2, fig. 3, 3a; pl. 4, fig. 5, 5a, 5b.

cf. 1977. *Phylloceras* (*Hypophylloceras*) *mikobokense* (COLLIGNON): KENNEDY and KLINGER, *Bull. Brit. Mus. Nat. Hist.* (*Geol.*) 27 (5): 368; pl. 12, fig. 1.

Material: Single specimen; OMNH. M2190, a fragmentary septate whorl, coll. by K. ICHIMICHI from loc. Aw7 (Nagata).

Description: The present specimen is represented by a fragment of the probable last portion of a septate whorl. As the preserved last part has the height of about 77 mm, the shell would be fairly large, presumably over 150 mm in diameter. The whorl is compressed elliptical in section with the gently inflated flanks, converging to a narrowly rounded venter, and the greatest breadth at about lower one-third of the flank, although the shell

around the umbilicus is secondarily compressed.

The ornaments consist of fine, dense striae and fold-like ribs. The striae are fairly flexiradiate, forming sinus near the umbilical shoulder and again at the upper part of the flank. The fold-like ribs, which are parallel to the striae, are marked only on the lower half of the flank and become obscure outward.

The suture is partly exposed, and of deeply and finely incised *Neophylloceras* pattern.

Discussion: The fairly large shell with fold-like ribs of the specimen from Awaji reminds us *Hypophylloceras* (*Neophylloceras*) *mikobokense* (COLLIGNON) from the lower Maastrichtian of madagascar (COLLIGNON, 1956, p. 24; pl. 2, fig. 3, 3a; pl. 4, fig. 5, 5a, 5b). But the ornaments of the present specimen are more flexuous than those of *H.* (*N.*) *mikobokense,* and the fold-like ribs are restricted on the lower flank.

The specimen from Awaji probably represents a new species which is allied to *H.* (*N.*) *mikobokense,* but it is too fragmentary to establish a new species. The assignment of COLLIGNON (1956)'s species to *Neophylloceras* will be probable, because it has deeply incised suture, having lost the phylloid termination, as has been mentioned by KENNEDY and KLINGER (1977, p. 369).

Occurrence: Fine sandy siltstone of the Seidan Formation at Nagata (Loc. Aw7); *Pachydiscus awajiensis* Zone.

Family Pachydiscidae SPATH, 1922

Genus *Pachydiscus* ZITTEL, 1884

Type species: *Ammonites neubergicus* HAUER, 1858 (subsequent designation by de GROSSOUVRE, 1894, p. 177).

Discussion: Generic diagnosis of this genus has been defined by MATSUMOTO (1947, p. 39; 1951, p. 23; 1954, p. 287) and WRIGHT (1957, p. L380). As has been mentioned by MATSUMOTO (1959c, p. 41; MATSUMOTO *et al.*, 1979, p. 50), three subgroups are recognized in this genus:

The first and typical subgroup (subgenus *Pachydiscus*) is characterized by the compressed whorl with oval or flat-sided section and the ribs which tend to differenciate into umbilical and ventral ones.

The second subgroup (subgenus *Neodesmoceras*) is characterized by almost smooth shell with remarkable weakening or disappearance of ribs at earlier growth stage.

The third subgroup has more inflated whorl than the typical subgroup, and the tendency of differenciation of ribs is not distinctly shown. For this subgroup, a new subgeneric name has not yet been proposed, but *Pachydiscus* (s.s.) is currently used for the sake of convenience.

I here follow MATSUMOTO's division. All axamined materials from Awaji are considered to belong to subgenus *Pachydiscus*.

Subgenus *Pachydiscus* ZITTEL, 1884

Pachydiscus (*Pachydiscus*) *awajiensis* MOROZUMI, n. sp.
Pl. 2, figs. 1-2; Pl. 3, figs. 1-2; Pl. 4, figs. 1-2; Text-fig. 4

Material: Holotype; OMNH. M2205, coll. by M. KUWANO from loc. Aw7 (Nagata). Paratypes; KS830417, KS830403-3, OMNH. M2199 (coll. by K. SAKAKIBARA) and M2216 (coll. by M. TAKADA), all from the same locality as that of the holotype.

OCU. MM341 and MM355 (coll. by Y. MAEDA) and THS442-860 and THS444-858 (coll. by S. YEHARA), all from loc. Aw8 (Hanzanji), are fragmentary internal moulds to be probably referable to the present species, although they should be called *Pachydiscus* (*P.*) sp. cf. *P.* (*P.*) *awajiensis*.

Measurements:

Specimen		D	B	H	B/H	U (%)
OMNH. M2205	(septate part)	115.5	ca. 31.4	50.5	0.61	31.2 (27.0)
〃	(−90°)	92.4	—	43.5	—	26.3 (28.5)
OMNH. M2216	(preserved end)	169.4	—	77.5	—	ca. 42.9 (25.3)
〃	(−270°)	88.0	29.2	39.9	0.73	23.4 (26.6)
KS830417	(preserved end)	133.4	41.8	60.5	0.69	ca. 35.4 (26.5)
〃	(−90°)	106.7	—	—	—	ca. 28.3 (26.5)

Diagnosis: Moderately distant, flexuous and sharp umbilical ribs, which show little weakening at the mid-flank and extend to the ventrolateral ones. The ventrolateral ribs are numerous, about three times as numerous as the umbilical ones.

Description: The shell is fairly large, being presumably about 200 mm in diameter at the full grown stage, with a shallow fairly narrow umbilicus. The whorl is narrowly elliptical in section and broadest at about lower one-third of the flank, having a gently inflated flank, a moderately arched venter and a nearly vertical umbilical wall.

The shell is ornamented by moderately distant, long umbilical ribs and numerous, regular, short ventrolateral ones. The umbilical ribs are thin, sharp and more prominent on the lower half of the flank, forming umbilical bullae on the inner whorls, but distinctly extend to the ventrolateral ones without remarkable weakening around the mid-flank. They are flexuous, being rursiradiate on the umbilical wall, prorsiradiate on the lower flank, almost rectiradiate for some distance above the mid-flank and passing again prorsiradiately on the upper flank with a gentle forward projection. The ventrolateral ribs are subparallel to and about three times as numerous as long umbilical ribs, and develop on the upper half of the flank except some ones extending downward to the umbilical shoulder. They are separated by somewhat wider interspaces.

There are 10 to 12 umbilical ribs and about 32 ventrolateral ones in a half of the outer septate whorl, although the ribs tend to increase in number with the shell growth. The ribs become somewhat thick and blunt on the body chamber, but persist even on the preserved last part of the whorl.

The suture is not well exposed in any specimen examined.

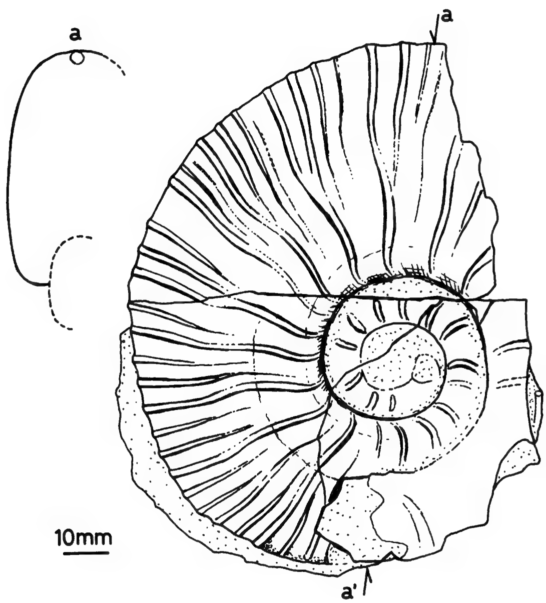

Fig. 4. *Pachydiscus awajiensis* MOROZUMI, n. sp.
Diagramatic sketch of the holotype, OMNH. M2205, showing a lateral view and a cross-section of whorls at a–a'.

Discussion: This species closely resembles *Pachydiscus* (*P.*) *excelsus* MATSUMOTO (*in* MATSUMOTO *et al.*, 1979, p. 50; pl. 8, fig. 1; text-fig. 2), from the probable lower part of the Hakobuchi Group (Middle Campanian ?) in the Hobetsu area, central Hokkaido, in having a narrowly elliptical whorl section, dense, long and rather flexuous umbilical ribs and numerous, projected ventrolateral ribs. The holotype of the latter species (monotypy) is very large, being estimated to be about 560 mm in diameter, and the shell of middle growth stage (corresponding to the size of Awaji specimens) is involved by the later whorl. Therefore, somewhat more numerous ribs and a little narrower umbilicus of *P.* (*P.*) *excelsus* described by MATSUMOTO may be interpreted as the features of somewhat later growth stage than that of Awaji specimens. However, the specimens from Awaji are always smaller, the largest example (KS830403-3) being about 150 mm in diameter at the last septum. Moreover, the specimens from Awaji have somewhat more flexuous, sharper and longer umbilical ribs than *P.* (*P.*) *excelsus*, without remarkable weakening around the mid-flank. Although the present species might represent a new geographical subspecies of *P.* (*P.*) *excelsus*, I here treat it as a distinct species, as *P.* (*P.*) *awajiensis*.

P. (*P.*) *awajiensis* is somewhat similar to *Pachydiscus* (*P.*) *subcompressus* MATSUMOTO (1954, p. 287; pl. 10, figs. 4–5) from the upper part (Rdy) of the Ryugase Group in southern Sakhalin in its shell form, dense umibilical ribs and numerous ventrolateral ribs, but has more distinctly flexuous ribs. The differenciation of umbilical and ventrolateral ribs and effacement of ribs in later growth stage are much more distinct in the latter species.

Pachydiscus (*P.*) *flexuosus* MATSUMOTO (*in* MATSUMOTO *et al.*, 1979, p. 53; pl. 9, figs. 1-3; pl. 10, fig. 4; pl. 12, fig. 1; text-fig. 4), from Unit D2 and Unit E2 (Maastrichtian) of the Tombetsu Valley, northern Hokkaido, has also rather flexuous ribs. However its umbilical ribs are not so dense, and the intercalation of ventrolateral ones are not so frequent as in *P.* (*P.*) *awajiensis*.

Pachydiscus (*P.*) *suciaensis* (MEEK) (USHER, 1952, p. 68; pl. 9, figs. 1-11; pl. 10, figs. 1-3; pl. 31, figs. 2-3), from the Upper Lambert and Northumberland Formations of the Nanaimo Group in Voncouver Island, British Columbia, has more inflated whorl, less flexuous ribs, more distant umbilical ribs and less frequent intercalation of ventrolateral ribs than *P.* (*P.*) *awajiensis.*

Occurrence: Fine sandy siltstone above the basal conglomerate of the Seidan Formation at Nagata (loc. Aw7). Fragmentary but comparable examples are from the "Shichi Shale" of the Anaga Formation at Hanzanji (loc. Aw8). These two localities seem to indicate almost the same horizon, although they belong lithostratigraphically to the different formations. At Nagata, *P.* (*P.*) *awajiensis* occurs abundantly, but other ammonites are scarcely found.

Pachydiscus (*Pachydiscus*) sp. aff. *P.* (*P.*) *awajiensis* MOROZUMI
Pl. 4, fig. 3

Material: Single specimen; THS. 442-855 (coll. by S. YEHARA), external cast, gypsum copy of which is GK. H9305, from loc. Aw8 (Hanzanji).

Description: As the specimen is only a fragmentary external cast, detailed observation is not possible. However, judging from the width of the umibilicus of about 40 mm, the entire shell would be fairly large. The umbilical wall is nearly vertical.

There are 11 to 14 long umbilical ribs per whorl. They arise at the umbilical seam, pass somewhat rursiradiate on the umbilical wall, and flex gently forward at the umbilical shoulder. As the upper flank of the outer whorl is not preserved, the ventrolateral ribs are almost unable to observe except for some ones extending downward to the lower flank.

Discussion: Among the pachydiscid ammonites from the "Shichi Shale", the present specimen shows somewhat different ornaments from the others, most of which being referable to *Pachydiscus* (*P.*) *awajiensis* established above. The umbilical ribs of the present specimen are apparently less numerous and also less flexuous than that of *P.* (*P.*) *awajiensis.*

In having 11 to 14 slightly flexous umbilical ribs per whorl, the present species is similar to *Pachydiscus* (*P.*) *suciaensis* (MEEK) from the Nanaimo Group in Vancouver Island, British Columbia (USHER, 1952, p. 68; pl. 9, figs. 1-11; pl. 10, figs. 1-3; pl. 31, figs. 2-3), as which MATSUMOTO (1978, p. 31) provisionally regarded it, but has a larger shell.

Anyhow as the present specimen is too fragmentary for the precise comparison, its treatment as *P.* (*P.*) aff. *awajiensis* is tentative.

Occurrence: "Shichi Shale" of the Anaga Formation at Hanzanji (loc. Aw8);

Pachydiscus awajiensis Zone.

Pachydiscus (*Pachydiscus*) sp. aff. *P.* (*P.*) *subcompressus* MATSUMOTO
Pl. 5, fig. 1; Pl. 7, fig. 1; Text-fig. 5

1951. *Pachydiscus subcompressus* MATSUMOTO (MS, *nom. nud.*): MATSUMOTO and MAEDA, *Minerals and Geology* 4 (3-4): 67; pl. 5, figs. 1-2.
cf. 1954. *Pachydiscus subcompressus* MATSUMOTO, *Cretaceous System in the Japan. Isl.*: 287; pl. 10, figs. 4-5 (*non* pl. 12, fig. 1).

Material: Single specimen; GK. H6883, the same specimen as that provisionally described and illustrated by MATSUMOTO and MEADE (1951), coll. by Y. MAEDA from loc. Aw16 (Yamamoto). It is secondarily compressed.

Measurements:

Specimen	D	B	H	B/H	U (%)
GK. H6883 (preserved end)	204.0	46.7	93.5	0.50	51.7 (25.3)
〃 (−90°)	169.5	37.2	80.3	0.46	43.0 (25.4)

Description: The shell is large. As the last septum is at the diameter of about 200 mm and the body chamber is only partly preserved, the complete shell would be over 300 mm in diameter.

The coiling is moderately involute, with a shallow, fairly narrow umbilicus measuring about 25 % of the diameter. Although secondarily compressed to a considerable degree, the whorl is compressed ovoid in section, with the greatest breadth at some way below mid-flank, having a gently inflated flank and a narrowly arched venter.

The shell is ornamented by moderately distant, bullate umbilical ribs and dense, regular, projected ventrolateral ribs; there are 16 umbilical ribs and about 65 ventrolateral ones on the outer whorl. The umbilical ribs are short, and develop on the lower half or lower third of the flank in the earlier half of the outer whorl; but in the later half of the outer whorl, they are more distant and more elongated, running prorsiradiately through the upper flank with some weakening and then extending to the ventrolateral ones. They are slightly flexiradiate, forming a sinus above the umbilical shoulder and a faint forward vent below mid-flank. The ventrolateral ribs are also short, but some of them extend downward to the mid-flank or even to the umbilical shoulder especially in the later growth stage, being separated regularly by the same interspaces. The ribs show some weakening on the siphonal zone and probably on the body chamber.

The suture is not well exposed, but is of complicatedly incised *Pachydiscus* type.

Discussion: With respect to the compressed shell form with a fairly narrow umbilicus, though deformed, numerous ventrolateral ribs and the only slightly flexuous umbilical bullate ribs, the present specimen closely resembles the illustrated holotype of *Pachydiscus* (*P.*) *subcompressus* MATSUMOTO (1954, p. 287; pl. 10, figs. 4-5) from the upper part (Rdy) of the Pyugase Group in South Sakhalin. That species, however, has more numerous but distinctly shorter umbilical ribs than the Awaji specimen at the late growth stage, and also

has a more smooth flank with a weakening of the ornaments at that stage except for the limited parts near the umbilicus and the venter.

In having umbilical ribs at wide intervals, the present species is fairly similar to *Pachydiscus* (*P.*) *gollevillensis* (D'ORBIGNY) from the Maastrichtian of Europe, Madagascar (COLLIGNON, 1971) and other area (ref. MATSUMOTO *in* MATSUMOTO *et al.*, 1979, p. 51), and also to *P.* (*P.*) *chrishna* (FORBES, 1848, p. 103; pl. 9, fig. 2) from the Valudayur beds of India. But the latter two species are rather small, being about 100 mm or so in diameter, and have flat-sided whorl and well differentiated umbilical and ventrolateral ribs. They have not so much elongated umbilibal ribs as the present specimen.

Anyhow, the Awaji specimen appears to be most closely akin to *P.* (*P.*) *subcompressus*, as which MATSUMOTO and MAEDA (1951) regarded it, taking the resemblance in shell-form and ornamentations at the middle growth stage into consideration. As MATSUMOTO (*in* MATSUMOTO *et al.*, 1979, p. 56) have mentioned, there exist some variations in the intensity of ribbing in *P.* (*P.*) *subcompressus*. Therefore the present specimen might be within the variation range of that species, but I treat is here as *P.* (*P.*) aff. *subcompressus*, since there are such dissimilar points as mentioned above.

Occurrence: Shimonada Fine Sandy Siltstone of the Shimonada Formation.

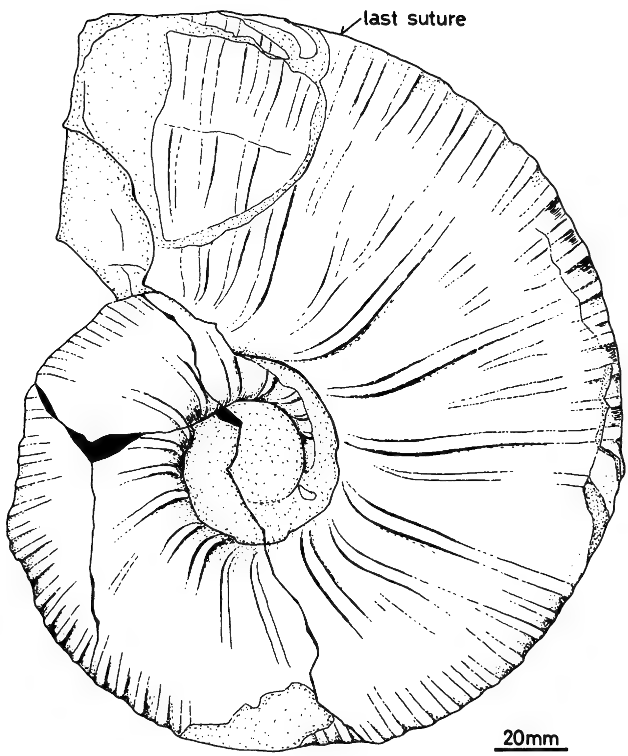

Fig. 5. *Pachydiscus* sp. aff. *P. subcompressus* MATSUMOTO.
Diagramatic sketch of GK. H6883, showing a lateral view.

Genus *Patagiosites* SPATH, 1953

Type species: *Ammonites patagiosus* SCHLÜTER, 1867 (original designation).

Discussion: *Patagiosites* is a pachydiscid with constrictions persisting up to a fairly late stage and ribs becoming weak or almost disappearing (SPATH, 1952, p. 38; WRIGHT, 1957, p. L380). Despite the SPATH's original diagnosis that the suture of *Patagiosites* should be of puzosid type, it is quite similar to that of *Anapachydiscus, Pachydiscus* or *Canadoceras*. WRIGHT (1957, p. L380) and MATSUMOTO (1959c, p. 60), therefore, regarded *Patagiosites* as a probable reduced derivative of *Canadoceras*, whom I follow in this paper.

JONES (1963, p. 45) considered that *Patagiosites* might be polyphylletic, since the inflated round-whorled forms which included the type species did not appear to have so closer relationship to *Canadoceras* as a group of compressed species.

Patagiosites laevis MOROZUMI, n. sp.

Pl. 6, fig. 1; Pl. 7, fig. 2

? 1800. *Patagiosites* (?) sp.: MATSUMOTO, *Geol. Paleont. Shimanto Belt*: 287; pl. 45, fig. 1.

Material: Holotype; JM386 (gypsum copy: OMNH. M2206), internal mould of a fairly large shell, form loc. Aw1 (Kiba). Paratype; SN01, a example of poor preservation, from the same locality as that of the holotype.

Measurements:

Specimen	D	B	H	B/H	U (%)
JM386 (at last septum)	159.4	47.9	62.9	0.76	55.9 (34.9)
〃 (60° later)	181.8	49.6	74.1	0.67	62.0 (34.1)

Diagnosis: Almost smooth shell but for periodic constrictions and associated collared ribs persisting to the adult stage; moderately wide umbilicus with a steep, subvertical umbilical wall in later stages.

Description: The shell is large with the last septum at the diameter of about 160 mm. The coiling is faintly involute, with an umbilicus of moderate width measuring about 34 % of the diameter. The whorl is higher than broad, ovoid in section, with a slightly convex flank and a narrowly arched venter, the greatest breadth being someway below mid-flank (about at lower one-third). The umbilical shoulder is rather abruptly rounded, to form a subvertical umbilical wall which increases its height toward the outer whorls.

The constrictions with associated collared ribs are countable 6 per whorl during the middle to late septate stages; they are somewhat more frequent on the body chamber, numbering 3 in a quarter whorl. These collars are low but distinct, being thickened and bluntly bullate at the umbilical shoulder; they are remarkably rursiradiate on the umbilical wall, and then almost prorsiradiate on the flank, forming a sinus at the umbilical shoulder and showing a slight projection on the venter. The constrictions are as broad as the collars, shallow but distinct in the middle growth stage, only bluntly deppressed in the next late whorl, and again deep on the body chamber. In front of some constrictions, faint

rib-like elevations are also observable. Except for the constrictions and associated collared ribs, the shell looks nearly smooth. If we examine more carefully, however, very faint ribs are irregularly discernible on some parts of the outer whorl.

The suture is well exposed and of finely and deeply incised *Pachydiscus* type, though it has been simplified to some extent by the secondary erosion.

Discussion: With respect to general shell form, *Patagiosites laevis* is closely related to *Patagiosites compressus* (MATSUMOTO, 1954, p. 310; pl. 20, figs. 1-3; text-fig. 31) from the Lower Sandy Siltstone of the Hakobuchi Group in the Tomiuchi area, central Hokkaido. It is due to secondary deformation that two specimens of *P. compressus,* GK. H3830 (holotype) and H3832, have somewhat more compressed whorls, as has been noticed by MATSUMOTO (1954). The middle-aged shell of *P. compressus* is, however, ornamented with weak but numerous ribs besides collared ones, in contrast with almost smooth shell of the present species. The constrictions are also deeper and sharper in *P. compressus* than in the Awaji specimens.

The present species is fairly similar to *Patagiosites alaskensis* JONES (1963, p. 45; pl. 38, figs. 1-3; pl. 39, figs. 1-3; pl. 40, fig. 1; pl. 41, figs. 1, 3, 7-8; text-figs. 24-25) from the upper part of Member 3 of the Matanuska Formation in southern Alaska, especially to such weakly ribbed varieties as represented by USNM131218 (holotype) and USNM131216. But *P. alaskensis* has weaker and almost disappearing constrictions and less prominent collared ribs without umbilical bullae in the late growth stage. On the average it has somewhat narrower umbilicus.

Occurrence: "Minato Shale" of the Seidan Formation; *Didymoceras awajiense* Zone.

Family Gaudryceratidae SPATH, 1927

Genus *Gaudryceras* de GROSSOUVRE, 1894

Type species: *Ammonites mitis* HAUER, 1866 (subsequent designation by BOULE, LEMOINE and THÉVENIN, 1906, p. 183).

Gaudryceras izumiense MATSUMOTO and MOROZUMI

Pl. 8, fig. 2

1980. *Gaudryceras izumiense* MATSUMOTO and MOROZUMI, *Bull. Osaka Mus. Nat. Hist.* (33): 12; pl. 11, fig. 1; pl. 12, fig. 1; pl. 13, fig. 1.

? 1980. *Gaudryceras izumiense* MATSUMOTO and MOROZUMI: MATSUMOTO, *Geol. Paleont. Shimanto Belt*: 288; pl. 47, fig. 1.

Holotype: OMNH.M1125, from loc. 7 (Sobura) of MATSUMOTO and MOROZUMI (1980), Azenotani Formation of the Izumi Group in the Izumi Mountains (original designation).

Material: Single specimen; MT01, an internal mould, from loc. Aw17 (Kuroiwa).

Measurements: The specimen has been secondarily compressed to a great extent, but has the following dimensions.

Specimen	D	B	H	B/H	U (%)
MT01 (preserved end)	199.3	—	83.0	—	59.3 (29.8)

Description: The shell is fairly large, with a moderately wide umbilicus, the body chamber occuping about three-forth of the outer whorl.

Ornaments of the outer whorl consist of fine numerous lirae and periodic narrow major ribs. The lirae on the ventrolateral part of the flank are about three to four times as numerous as those on the umbilical margin, being irregularly intercalated or bifurcated at the umbilical shoulder and at mid-flank. The major ribs develop bluntly every 30°-40°. They are flexiradiate, forming a broadly convex curve on the lower half of the flank and a slight projection on the ventrolateral part. Probable apertural margin is almost parallel to the ornaments.

Ornaments of the inner whorls are not well preserved, but for rather coarse lirae at the umbilical shoulder.

Discussion: Although the present specimen is deformed, the above observation agree well with the diagnosis of *Gaudryceras izumiesse* MATSUMOTO and MOROZUMI (1980, p. 12) known from the probable Maastrichtian part of the Izumi Group in the Izumi Mountains. A little narrower umbilicus of the Awaji specimen is considered to be due to secondary compression, and somewhat coarser lirae also due to absence of the test.

Gaudryceras sp. provisionally described by MATSUMOTO (1980, p. 289, 294; pl. 46, figs. 3-5; pl. 47, figs. 3-6) from the Nakamura Formation of Shikoku has some resemblance with the present specimen, but has much wider umbilicus and coarser subcostae on the outer whorl.

Occurrence: The specimen was found from a floated nodule, probably derived from the Shimonada Formation. *G.* cf. *izumiense* has recently been recognized to occur in the D Formation of the Hakobuchi Group in the Tombetsu Valley, Hokkaido (MATSUMOTO *et al.*, 1981a).

Gaudryceras sp. aff. *G. striatum* (JIMBO)

Pl. 8, fig. 1

cf. 1894. *Lytoceras striatum* JIMBO, *Paläont. Abhandl.* 6 (N. F. 2) (3): 181; pl. 6, fig. 6, 6a, 6b.
cf. 1903. *Gaudryceras striatum* (JIMBO): YABE, *Jour. Coll. Sci., Imp. Univ. Tokyo* 18 (2): 31; pl. 4, figs. 5-6.

Material: Single specimen; OMNH. M2200, a fragmentary septate whorl, coll. by M. TANI from loc. Awl (Kiba).

Description: The present specimen is represented by a fragmentary, probably last portion of, septate whorl, of which the lower flank near the umbilicus is not preserved.

The shell is very large, the entire shell presumably attaining 500 mm in diameter, as the preserved last part has the height over 120 mm though incomplete. The whorl is higher than broad, and subquadrate in section with a broadly rounded venter, being broadest at the lower part of the flank.

Ornaments consist of very fine numerous lirae and thick major ribs; the former is discernible only on the surface of the preserved test; the latter is comparatively closely set, countable up to 2, and gently sigmoidal, having a slight forward projection on the venter.

Discussion: The present specimen is so fragmentary that the precise comparison cannot be done, but it resembles adult forms of *Gaudryceras striatum* (JIMBO) such as those described and illustrated by YABE (1903, p. 31; pl. 4, figs. 5-6) from Abeshinai of Hokkaido in its thick major ribs and very fine, numerous lirae. It is, however, extremely larger and has less sigmoidal major ribs than the examples from Hokkaido.

In having thick major ribs, the present species is somewhat similar to *Gaudryceras crassicostatum* (JIMBO, 1894, p. 36; pl. 6, fig. 7, 7a) from Soya of Hokkaido, but the latter has smaller shell, less than 140 mm in diameter in the holotype, and coarser lirae.

Anyhow, as the Awaji specimen is most closely related to *G. striatum* among the formerly described gaudryceratids, I treat here it as *G.* sp. aff. *G. striatum* (JIMBO). Some verieties of *G. striatum* discriminated by YABE (1903, p. 33) and MATSUMOTO (1942b, p. 666) are currently regarded as invalid.

Occurrence: "Minato Shale" of the Seidan Formation; *Didymoceras awajiense* Zone. *G. striatum* has been also recorded from the Izumi Group in Shikoku (NODA and TASHIRO, 1973) and from the B Formation of the Hakobuchi Group in the Tombetsu Valley, Hokkaido (MATSUMOTO *et al.*, 1980b) besides the type locality.

Genus *Vertebrites* MARSHALL, 1926

Type species: Vertebrites murdochi MARSHALL, 1926 (original designation).

Discussion: Taxonomical treatment of *Vertebrites* varies among authors. MATSUMOTO (1959c, p. 145) ranked it as a subgenus of *Gaudryceras*, whereas WIEDMANN (1962, p. 150) treated it as the sole member of newly proposed subfamily Vertebritinae. I here follow MARSHALL (1926, p. 138), COLLIGNON (1956, p. 64), HENDERSON (1970, p. 22) and KENNEDY and KLINGER (1979, p. 156), and treat *Vertebrites* as an independent genus.

Several species of *Gaudryceras*, as typically represented by *G. hamanakense* MATSUMOTO and YOSHIDA, 1979, have similar character of ornament to that of *Vertebrites*, which was called "*Vertebrites*-like ornament" by MATSUMOTO and YOSHIDA (1979, p. 68). Therefore, *Vertebrites* can be distinguished from *Gaudryceras* essentially by examining the internal suture, which have proliferated umbilical lobes decreasing in size from the antisiphonal line to the umbilicus. As the suture is not exposed on the specimen from Awaji, this description under *Vertebrites* is provisional.

Vertebrites (?) sp. cf. *Vertebrites kayei* (FORBES)
Pl. 9, fig. 3; Text-fig. 6

cf. 1846. *Ammonites kayei* FORBES, *Trans Geol. Soc. London, Ser. 2,* 7: 101; pl. 8, fig. 3.

cf. 1895. *Lytoceras* (*Gaudryceras*) *kayei* (FORBES): KOSSMAT, *Beitr. Paläont. Geol. Öst.-Ung.* 9: 124, 126; pl. 16, fig. 5a, b; pl. 17, fig. 2a, b.

cf. 1956. *Vertebrites kayei* (FORBES): COLLIGNON, *Ann. Géol. Serv. Mines, Madagascar* 23: 64; pl. 6, fig. 4, 4a, 4b.
cf. 1958. *Lytoceras* (*Gaudryceras*) *coalingense* ANDERSON, *Geol. Soc. Amer., Memoir* 71: 184; pl. 68, fig. 1.
cf. 1958. *Lytoceras* (*Gaudryceras*) *birkhauseri* ANDERSON, *Ibid.* 71: 185; pl. 68, fig. 4, 4a.
cf. 1959. *Gaudryceras* (*Vertebrites*) *kayei* (FORBES): MATSUMOTO, *Mem. Fac. Sci., Kyushu Univ., Ser. D.* (*Geol.*), Spec. Vol. 1: 146.
1967. *Gaudryceras* (*Vertebrites*) sp. cf. *kayei* (FORBES): SUYARI, BANDO and OBATA, *Jour. Geol. Soc. Japan* 73 (11): 536; text-figs. 4-5.
? 1979. *Vertebrites kayei* (FORBES): KENNEDY and KLINGER, *Bull. Brit. Mus. Nat. Hist.* (*Geol*) 31 (2): 160; pl. 14, fig. 2; text-figs. 4-5.

Material: Single specimen; OCU. MM351, coll. by K. ICHIKAWA and Y. MAEDA from loc. Aw15 (Haraikawa) (=loc. 61a of ICHIKAWA and MAEDA).

Measurements:

Specimen		D	B	H	B/H	U (%)
OCU. MM351	(preserved end)	75.5	20.8	25.6	0.81	33.1 (43.8)
〃	(−90°)	64.2	13.4	15.5	0.86	28.6 (44.5)

Description: The shell is moderate in size, evolute and polygyral, having 9 septate whorls and the body chamber of about one volution, with a shallow, fairly wide umbilicus measuring about 45 % of the diameter.

The whorl is much broader than high in early growth stage, about two times as broad as high, and depressed crescent in section; it increases gradually in height with growth, becoming approximately as broad as high with a subcircular section in the last septate whorl, and then becoming higher than broad with a more narrowly arched venter, gently inflated flank and somewhat abruptly rounded umbilical shoulder in the body chamber, though the body chamber is secondarily compressed. The whorl overlaps about one-third to nearly a half of the next inner whorl, with the greatest breadth at or near the umbilical

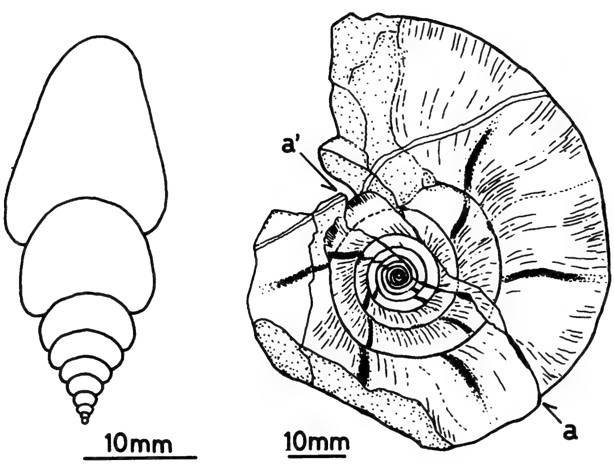

Fig. 6. *Vertebrites* (?) sp. cf. *V. kayei* (FORBES). Diagramatic sketch of OCU. MM351, showing a lateral view and a natural whorl-section at a-a′.

shoulder.

The surface of the shell is ornamented with numerous, fine lirae which run obliquely forward on the umbilical wall and shoulder, and then slightly rursiradiately on the main part of the flank, showing a slight projection on the venter. The lirae become more numerous and finer outward, being intercalated by somewhat finer lirae at or near the umbilical shoulder and somewhere on the flank. They are somewhat weakened outward, and not impressed on the internal mould.

There are shallow periodic constrictions which are pararell to the lirae, numbering about 4 to 5 per whorl; they are well marked around the umbilical shoulder, and obscure on the upper flank. Any collared rib or major rib is not observable on the present specimen.

The suture is not well exposed.

Discussion: The specimen of *Ammonites kayei* FORBES, 1846 illustrated by FORBES (1846, p. 101; pl. 8, fig. 3), BM.C51050, which has been designated as the lectotype by KENNEDEY and KLINGER (1979, p. 162) and independently by MATSUMOTO and YOSHIDA (1979, p. 72), is a small, probably immature specimen from Pondicherry, India. KOSSMAT (1895, p. 124, 162) redescribed the species in detail based on more specimens from the type locality, and supplemented the specific diagnosis, which was concisely recorded by MATSUMOTO (1959c, p. 147). The observed characters of the specimen from Awaji coincide well with that diagnosis.

The present specimen is identical with the specimen, NSM. 6632, from the Hinotani Group of the Shimanto Belt in Shikoku, which has been briefly described as *Gaudryceras* (*Vertebrites*) sp. cf. *kayei* (FORBES) (SUYARI *et al*., 1967, p. 536; figs. 4-5), in shell form and surface ornamentations. That specimen from Shikoku also has numerous, fine lirae, periodic constrictions and no major rib, and seems to have a *Vertebrites*-type internal suture, though much eroded.

The present species fairly resembles *Gaudryceras hamanakense* MATSUMOTO and YOSHIDA (1979, p. 68; pl. 10, figs. 1-3; pl. 11, figs. 1-2; text-fig. 2) from the Akkeshi Formation (Maastrichtian) of the Nemuro Group in the Hamanaka area, eastern Hokkaido, in having a polygyral shell, wide umbilicus and numerous fine lirae. However, the latter species has the suture of typical *Gaudryceras* pattern and frequent major ribs on the adult living chamber. The outward multiplication of lirae is more remarkable in *G. hamanakense* than in the present species.

Occurrence: Shimonada Fine Sandy Siltstone of the Shimonada Formation; *Pachydiscus* aff. *subcompressus* Zone.

There are many ammonites reported from various horizons in various regions as *Vertebrites kayei*. KENNEDY and KLINGER (1979, p. 163), therefore, considered that *V. kayei* had lived long, ranging from the Santonian to Maastrichtian age. But, some examples of them may need restudy, as has been pointed out by MATSUMOTO and YOSHIDA (1979, p. 72), because it is difficult to identify *V. kayei* unless the internal suture is examined. I think that *V. kayei* is restricted to the Lower Maastrichtian.

Genus *Anagaudryceras* SHIMIZU, 1934

Type species: *Ammonites sacya* FORBES, 1846 (original designation).

Discussion: *Anagaudryceras* is small- to medium-sized gaudryceratid characterized by very fine lirae of the shell throughout its life and fold-like ribs on the body chamber. The generic diagnosis has been defined by MATSUMOTO (1942b, p. 669), WRIGHT and MATSUMOTO (1954, p. 113), WRIGHT (1957, p. L200) and KENNEDY and KLINGER (1979, p. 144).

HOWARTH (1965, p. 357) and KENNEDY and KLINGER (1979, p. 146) recognized two species groups in *Anagaudryceras*; one is the group of *A. sacya* which is characterized by fold-like ribs on the body chamber and well marked constrictions on earlier whorls; the other is the group with only weak constrictions and no fold-like rib on the body chamber, which KENNEDY and KLINGER (1979) call "the group of *A. involvulum*".

As has been well understood, the type specimen of *Ammonites sacya* FORBES (1846, p. 113; pl. 14, fig. 10) is a small immature one, and a fragment of a probable body chamber of the same species has another specific name, *Ammonites buddha* FORBES (1846, p. 112; pl. 14, fig. 9). On this account, WHITEAVES (1884, p. 203), MATSUMOTO (1959a, p. 72) and HOWARTH (1965, p. 358) regarded *A. buddha* as a synonym of *A. sacya*, whereas KENNEDY and KLINGER (1979, p. 146) adopted *A. buddha* as a name of that species by the reason that the name *buddha* had page priority. But I, for the present, follow WHITEAVES (1884) to use *A. sacya* as a valid specific name.

Anagaudryceras matsumotoi MOROZUMI, n. sp.
Pl. 9, fig. 1; Text-fig. 7

1942. *Anagaudryceras ryugasense* MATSUMOTO (*nom. nud.*), *Jour. Geol. Soc. Japan* 49: 101; only listed.
1942. *Anagaudryceras ryugasense* MATSUMOTO (*nom. nud.*): MATSUMOTO, *Proc. Imp. Acad. Japan* 18 (10): 666; only listed.
1960. *Anagaudryceras ryugasense* MATSUMOTO (*nom. nud.*): ICHIKAWA and MAEDA, *Yukochu* (11): 10; only listed.

Material: Holotype; GK. H6882, coll. by Y. MAEDA from loc. Aw15 (Haraikawa) (= loc. 210A of MAEDA), the body chamber of which has been secondarily compressed and the test is only partly preserved.

The following specimens are designated as paratypes, though they are not materials from Awaji but from Hokkaido and Sakhalin: GT. I-3785, coll. by T. MATSUMOTO from loc. N109c, Zone Rdy (lower part) of the Ryugase Group, southern Sakhalin; GK. H5980, coll. by Y. IGI from loc. P-240, E Formation (lower part) in the Tombetsu Valley, northeastern Hokkaido; GK. H5981 and H5982, coll. by S. NISHIJIMA from loc. Nj-68, C Formation in the Tombetsu Valley; GK. H5983, coll. by T. MATSUMOTO from loc. Nm175, Unit N4 of the Nemuro Group, eastern Hokkaido; GK. H5984, coll. by H. KIDO and T. MATSUMOTO from loc. Kd1404, Senposhi Formation of the Nemuro Group.

Measurements:

Specimen		D	B	H	B/H	U (%)
GK. H6882	(at preserved end)	45.5	16.2	20.0	0.81	13.6 (29.9)
〃	(−30° from above)	42.7	14.0	19.0	0.74	13.5 (31.6)
〃	(at last septum)	—	12.5	11.8	1.06	10.4 (—)
GK. H5980		52.4	—	23.8	—	15.0 (28.6)
GT. I-3785		33.0	13.3	12.8	1.04	12.1 (36.7)

Diagnosis: Fairly small shell with a moderately wide umbilicus which becomes proportionately smaller with the shell growth; somewhat compressed body chamber without fold-like ribs, but with distantly spaced shallow constrictions.

Description: The shell is fairly small, being less than 60 mm in diameter at the full-grown stage. The degree of involution of whorls is moderate, but increases progressively with the shell growth, and as a result the umbilicus becomes proportionately smaller, being about 30 % of the diameter at the last volution. The whorl is depressed, reniform in section in early growth stage, but becomes almost as high as broad, subcircular in section in middle growth stage near the last septum; it is higher than broad, broadly ovate in section on the body chamber, having a broadly rounded venter, subrounded umbilical shoulder and the greatest breath at the lower part of the flank.

The shell surface is ornamented by very fine lirae which pass straight up the umbilical wall, are slightly prorsiradiate on the lower flank, and then almost rectiradiate across the main part of the flank, forming a faint forward curve at the umbilical shoulder.

The last whorl is ornamented by shallow and narrow constrictions (or fullows) which run parallel to the lirae; they are more closely spaced on the body chamber than on the septate part, numbering 8 to 10 in the last volution. The constrictions are associated, at the back of them, with faint collar-like elevations which are as broad as constrictions. Both collars and constrictions are also covered with lirae.

The suture is not well exposed.

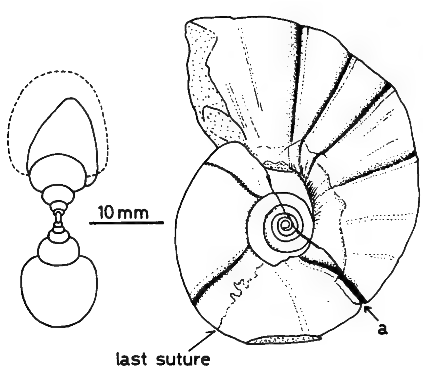

Fig. 7. *Anagaudryceras matsumotoi* MOROZUMI, n. sp.
Diagramaic sketch of the holotype, GK. H6882, showing a lateral view and a natural whorl-section at a.

Discussion: The specimen from Awaji was formerly listed by ICHIKAWA and MAEDA (1960, p. 10) as "*Anagaudryceras ryugasense* MATSUMOTO", based on MATSUMOTO's identificaton. Although "*A. ryugasense*" is a nomenclaturially invalid name because it has not yet been formally described, the name has appeared in some biostratigraphic papers since MATSUMOTO (1942a, p. 101) first used it. Through the kindness of Dr. T. MATSUMOTO, I had a opportunity of studying several specimens from Hokkaido and Sakhalin which were under his study to be described as *A. ryugasense*. The Awaji specimen is quite similar to and possibly identical with them in shell form and in ornamentations. In these circumstances, I here give it a new specific name, *A. matsumotoi*, to validate that species, selecting the Awaji specimen as the holotype and forsaking "*ryugasense*" with MATSUMOTO's permission, because "Ryugase" was a place name in southern Sakhalin, now outside Japan.

In having somewhat compressed body chamber without remarkable fold-like ribs, *A. matsumotoi* belongs to "the group of *Anagaudryceras involvulum*" (KENNEDY and KLINGER, 1979), and has similar measurements to those of *A. involvulum* (STOLICZKA, 1865, p. 150; pl. 75, fig. 1, 1b) from the Ootatur Group (Cenomanian-Turonian) of India. The Indian species, however, seems to me to be indefinite, since it is represented by only one specimen of septate stage illustrated by STOLICZKA (1865), and the nature of the adult shell is not known. Precise comparison of *A. matsumotoi* with *A. involvulum* is impossible.

Anagaudryceras mikobokense COLLIGNON (1956, p. 68; pl. 8, fig. 1) from the Lower Maastrichtian of Madagascar and *A. politissimum* (KOSSMAT, 1895, p. 128; pl. 15, fig. 7a-c) from the Turonian-Santonian of India are different from the present species in having larger shell diameter, wider umbilicus and less compressed whorl at the corresponding diameter.

Japanese allied species, *A. yokoyamai* (YABE, 1903, p. 36; pl. 6, figs. 1-2; pl. 7, fig. 6′) and *A. yamashitai* (YABE, 1903, p. 38; pl. 4, fig. 7) from the Upper Yezo Group in Hokkaido, somewhat resemble *A. matsumotoi* in having a fairly narrow umbilicus, but are much larger and have distinct ribs on the body chamber.

Occurrence: Shimonada Fine Sandy Siltstone of the Shimonada Formation; *Pachydiscus* aff. *subcompressus* Zone.

Genus *Zelandites* MARSHALL, 1926

Type species: *Zelandites kaiparaensis* MARSHALL, 1926 (original designation).

Discussion: *Zelandites* was originally erected by MARSHALL (1926, p. 147) as a monotypic genus represented by *Z. kaiparaensis* MARSHALL, *"Gaudryceras" varuna* (FORBES), type species of *Varunaites* SHIMIZU, 1926, being excluded from it. Afterwards, this genus was emended to include certain "gaudryceratids" of *varuna*-group. Besides *Varunaites, Hypogaudryceras* SHIMIZU, 1934 and *Anazelandites* MATSUMOTO, 1938 have also been regarded as synonyms of *Zelandites* (WRIGHT and MATSUMOTO, 1954, p. 113; WRIGHT, 1957, p. L200; MATSUMOTO, 1959c, p. 148; KENNEDY and KLINGER, 1979, p. 163).

Zelandites sp. cf. *Z. varuna* (FORBES)

Pl. 9, fig. 2; Text-fig. 8

cf. 1846. *Ammonites varuna* FORBES, *Trans. Geol. Soc. London, Ser. 2,* 7: 107; pl. 8, fig. 5.
cf. 1895. *Lytoceras* (*Gaudryceras*) *varuna* (FORBES): KOSSMAT, *Beitr. Paläont. Geol. Öst.-Ung.* 9: 130.
cf. 1983. *Zelandites varuna* (FORBES) var. *japonica* MATSUMOTO, *Japan. Jour. Geol. Geogr.* 15 (3-4): 140; pl. 14, figs. 5-7; text-fig. 1.

Material: Single specimen; OCU. MM352, coll. by K. ICHIKAWA and Y. MAEDA, from loc. Aw15 (Haraikawa)(=loc. 6la of ICHIKAWA and MAEDA).

Measurements:

Specimen		D	B	H	B/H	U (%)
OCU. MM352	(preserved end)	22.9	7.5	10.6	0.71	5.7 (24.9)
〃	(−90°)	17.9	6.0	8.0	0.75	4.9 (27.4)

Description: The shell is small, consists of five volutions, marking a trace of umbilical seam of about two-third still more volution. The coiling is moderately involute, with a shallow, fairly narrow umbilicus of about 25 % of the diameter. The outer whorl is higher than broad, ovoid in section, with the greatest breadth at lower one-third of the flank, and converges to a narrowly arched venter. The umbilical shoulder is broadly rounded with a gently sloping umbilical wall.

The surface of the shell is almost smooth but for fine growth-lines and faint, almost unnoticeable narrow furrows. They are rectiradiate on the umbilical wall, and rather prorsiradiate on the main part of the flank, forming a slight forward curve. Ornaments of the inner whorls are not observable.

The suture is not exposed.

Discussion: The present specimen has an old lavel of "*Zelandites varuna* (FORBES)" written by T. MATSUMOTO, and is probably the same as that formerly listed by ICHIKAWA and MAEDA (1960, p. 10) as *Hauericeras* cf. *rembda* (FORBES), although it is not identical with the latter species.

Zelandites varuna (FORBES, 1846, p. 107; pl. 8, fig. 5) was established based on a so insufficient material, probably of immature stage, from India that the described nature of it is not good enough for the exact comparison. But the above observation of the Awaji specimen agrees well with the diagnosis of *Z. varuna* which was supplemented by KOSSMAT (1895, p. 130) and MATSUMOTO (1938, p. 142).

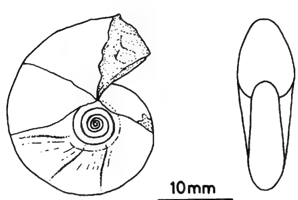

Fig. 8. *Zelandites* sp. cf. *Z. varuna* (FORBES).
Diagramatic sketch of OCU. MM352, showing lateral and frontal views.

Z. varuna var. *japonica* MATSUMOTO (1938, p. 140; pl. 14, figs. 5-7; text-fig. 1) from the upper part (Rdy) of the Ryugase Group in southern Sakhalin is most closely allied to the present species, but has a more compressed whorl and a narrower umbilicus.

Occurrence: Fine sandy siltstone of the Shimonada Formation. This species has been recently recorded from the C Formation of the Hakobuchi Group in the Tombetsu Valley, northern Hokkaido (MATSUMOTO *et al.*, 1980b).

Family Tetragonitidae HYATT, 1900

Genus *Saghalinites* WRIGHT and MATSUMOTO, 1954

Type species: *Ammonites cala* FORBES, 1846 (original designation).

Discussion: *Saghalinites* was originally established as a subgenus of *Epigoniceras* SPATH, 1925 by WRIGHT and MATSUMOTO (1954, p. 110), taking very evolute whorl, wide umbilicus, slowly increasing whorl height and rounded or octagonal whorl section as the characteristics of it. I here follow COLLIGNON (1956, p. 95), BIRKELUND (1965, p. 30; 1982, p. 15) and MATSUMOTO (1980, p. 290), and treat *Saghalinites* as an independent genus.

Saghalinites (?) sp.
Pl. 7, fig. 3

Material: Two specimens; OCU. MM353 and MM354, coll. by K. ICHIKAWA and Y. MAEDA from loc. Aw15 (Haraikawa) (=loc. 44a of ICHIKAWA and MAEDA).

Measurements:

Specimen	D	B	H	B/H	U (%)
OCU. MM353 (−100° from the preserved end)	58.0	14.9	22.8	0.65	22.5(38.8)

Description: Both specimens from Awaji are poorly preserved, and the description is based on relatively better one of them, OCU. MM353.

The coiling is relatively evolute, with a shallow, moderately wide umbilicus. The whorl is ovoid in section with a broadly rounded umbilical shoulder, moderately inflated flank and relatively narrowly arched venter, the greatest breadth being a little way below mid-flank.

The surface of the most part of outer whorl is almost smooth but for constrictions, which run prorsiradiately and are countable up to 4. On only limited part near the preserved end, probably near the aperture, a few, faint rib-like elevations are discernible; they are also prorsiradiate. The ornaments of the inner whorl are not observable due to poor preservation.

Discussion: The hitherto described species of *Saghalinites* are very few. *S. nuperus* (van HOEPEN) from the Santonian of Madagascar (COLLIGNON, 1956, p. 95; pl. 11, fig. 1, la, lb) has more inflated whorl, and *S. wrighti* BIRKELUND (1965, p. 30; pl. 1, fig. 5; pl. 2, figs. 1-5; pl. 3, fig. 1; text-figs. 14-25) has a wider umbilicus and less prominent constrictions on

the outer whorl than the present specimens. Anyhow, the specimens from Awaji are too poor for the precise comparison.

Occurrence: "Shimonada Whitish Sandstone" of the Shimonada Formation at Haraikawa (loc. Aw15); *Pachydiscus* aff. *subcompressus* Zone.

Family Nostoceratidae HYATT, 1900

Taxonomical treatment of some genera in Nostoceratidae differs considerably even among recent authors (e.g. WRIGHT, 1957; MATSUMOTO, 1959c, 1967b, 1977a; HOWARTH, 1965; LEWY, 1967, 1969; WIEDMANN, 1962; KLINGER, 1976). I can not discuss more for the present, and treat *Didymoceras, Nostoceras, Pravitoceras* and *Solenoceras* as distinct genera in Nostoceratidae, following HOWARTH (1965) and MATSUMOTO (1967b; 1977a).

Genus *Didymoceras* HYATT, 1894

Type species: *Ancyloceras nebrascense* MEEK and HAYDEN, 1856 (original designation).

Discussion: *Didymoceras* was regarded as a synonym of *Cirroceras* CONRAD, 1868 [type species: *Ammonceratites conradi* MORTON, 1841] by WRIGHT (1957, p. L224) and WIEDMANN (1962, p. 195). The holotype of *A. conradi* is, however, based on a so imperfectly preserved specimen that *Cirroceras* is currently treated as *nomen dubium* (an unusable generic name), as considered by HOWARTH (1965, p. 371-372) and followed by MATSUMOTO (1967b, p. 339) and KLINGER (1976, p. 63). Thus, *Didymoceras* is generally accepted as a distinct valid genus. *Emperoceras* HYATT, 1894 [type species: *Heteroceras simplicostatum* WHITFIELD] is regarded as a synonym of *Didymoceras* (MATSUMOTO, 1967b, p. 337; COBBAN, 1970, p. D72; LEWY, 1969, p. 111; KLINGER, 1976, p. 63). Although KLINGER (1976, p. 63-64) interprets *Didymoceras* as an extended genus, including *Bostrychoceras, Eubostrychoceras* and *Nostoceras*, I treat here it in the sense defined by HOWARTH (1965, p. 372) and MATSUMOTO (1967b, p. 337).

There are significant differences in the mode of coiling in early growth stage among the species which are currently treated as *Didymoceras*. According to GILL and COBBAN (1973, fig. 5) 's restorations, for example, *D. nebrascense* (MEEK and HAYDEN) has early whorls consisting of straight limbs, and *D. stevensoni* (WHITFIELD) and *D. cheyennense* (MEEK and HAYDEN) have loosely coiled spiral ones, whereas such species as *D. hornbyense* (WHITEAVES), *D. secoense* (YOUNG) and *D. awajiense* (YABE) seem to constitute closely coiled spire in early stage. Further study is required to know the taxonomic implications of these differences.

In Japan two species of *Didymoceras, D. awajiense* (YABE, 1901) and *D. nakaminatoense* (SAITO, 1958), have hitherto been described. The name "*Didymoceras awajiense*" has frequently appeared in subsequent biostratigraphical papers, but MATSUMOTO (1977a, p. 323) and MATSUMOTO *et al.* (1981b, p. 175) have suggested that there seems to be more than one species in the materials treated as "*D. awajiense*", and that *D. awajiense* needs a

critical revision.

Didymoceras awajiense (YABE)
Pl. 10, figs. 1–4; Pl. 11, fig. 1; Pl. 12, figs. 1–2; Pl. 13, figs. 1–2;
Pl. 14, figs. 1–2; Pl. 15, figs. 1–3; Text-figs. 9–11

1901. *Hamites* (*Anisoceras*) *awajiensis* YABE, *Jour. Geol. Soc. Tokyo* 8: 2; text-fig. 1a, 1b, 1c.
1915. *Turrilites* (*Hyphantoceras*) *oshimai* (YABE) var.: YABE, *Sci. Rep. Tohoku Imp. Univ., 2nd Ser.* 4 (1): 18; pl. 1, fig. 1a, 1b.
1915. *Turrilites* (*Bostrychoceras*) *otsukai* (YABE): YABE, *Ibid.* 4 (1): 16; pl. 1, figs. 2–3.
1936. *Bostrychoceras awajiense* (YABE): SASAI, *Jour. Geol. Soc. Japan* 43: 599; pl. 29.
1958. *Nostoceras awajiense* (YABE): SAITO, *Bull. Fac. Lib. Arts, Ibaraki Univ., Nat. Sci.* (8): 87; pl. 1, figs. 1–2; pl. 2, figs. 1–2; pl. 3, figs. 1–3; pl. 4, figs. 1–3; text-figs. 3–5.

Material: The specimen described by YABE (1901, p. 2; text-fig. 1a–c), consisting of a fragmentary whorl in middle growth stage from Awaji Island without precise locality record, is not kept in the University Museum, University of Tokyo. About 40 years have passed since the original specimen was lost. A fairly well preserved specimen illustrated by SASAI (1936, pl. 29) is also missing. Therefore, among the specimens ever described or illustrated from Awaji, the only one, IGPS. 4533 described by YABE (1915, p. 18; pl. 1, fig. 1a, 1b) from Anaga (probably loc. Aw1 of the present study) as *Turrilites* (*Hyphantoceras*) *oshimai* (YABE), is accessible at present. It is not, however, identical with *Heteroceras oshimai* YABE, 1904, as MATSUMOTO (1977a, p. 310) has pointed out, but unmistakably identical with the present species as has been already noticed by SASAI (1936, p. 598). It is here designated as the neotype to be proposed to the ICZN.

There are many, recently collected specimens of good preservation which well supplement the above for the present description; they are as follows:

OMNH. M2215 (coll. by M. SATO), MS03, KI02, JM141, TN01, TN820620-1 and TN820620-2, immature specimens with fairly well preserved shell of early growth stage, all from loc. Aw1 (Kiba);

OMNH. M2211 and M2212 (coll. by M. SATO), MS06, MS10, MS11, MT709 and SN04, fairly well preserved adult specimens with retroversal body whorl, all from loc. Aw1 (Kiba);

MS07, OMNH. M2213 and M2214 (coll. by M. SATO), KI820331 and KS770403, considerable parts of spiral whorl or body chamber, all from loc. Aw1 (Kiba).

The following, relatively well preserved specimens in old collections have been also examined:

OMNH. M1142 and M1165, coll. by S. HADA from Anaga; GH. NM. Na-04 and NM. Na-05, coll. by M. NAKANO from Nakano; KU. JM11326 (=HIRASE Coll. 0-26), specimen with a severely injured body chamber, and KU. JM11327 (=HIRASE Coll. 0-24), both from Anaga; KU. JM11319, coll. by T. HINO from Nakano; THS. 389-1, coll. by T. SAWADA from Anaga, and THS. 389-2, coll. by S. YEHARA from Kominato.

Many other fragmentary specimens are omitted from the list above.

Measurements:

Specimen	Height of the entire shell	Height of the spire	Length of C-form	D1	D2
OMNH. M2211	158+	75 [3]	141	105.9	69.2
OMNH. M2212	170+	120 [3]	ca. 120	89.3	82.7
MS06	165+	96 [2]	ca. 140	119.8	96.9
MS07	—	78 [3]	—	107.1	94.1
MS10	169	112 [4]	129	103.3	93.7
MS11	127+	69 [2]	110	97.8	76.0
SN04	174	111 [3]	106	94.0	78.2
TN01	—	40 [5]	—	106.0	61.9
TN820620-2	—	27 [5]	—	ca. 40.0	21.0

D1: Diameter of the preserved last spiral whorl (at or near the last septum)
D2: Diameter at D1-360°
[ ]: number of preserved whorls of the spire

Description: The shell, consisting of a low, spiral phragmocone and a suspended, retroversally C-shaped body whorl, is fairly large, with the diameter of the last spiral whorl about 100-120 mm and the length of C-form about 100-140 mm. The coiling is dextral or sinistral, and polygyral with rather slowly enlarging whorls and a circular whorl section.

The spire in early growth stage (*less than 15 mm in diameter*) is rather low, with an apical angle of about 60°-70°, consisting of four or so volutions, though the shell of very initial stage is not preserved in any specimen examined. The whorls of this stage are just touching each other, some lower part of the earlier whorl being embraced with the later one.

In middle growth stage (*during 15-60 mm in diameter*), the spire becomes very low, being nearly planispiral in most specimens but not so low in a few specimens, and has free, slightly separated whorls in about two volutions, with a fairly wide umbilicus. The mode of coiling of this stage may be maintained to a little later stage in some specimens.

In later stages (*more than 60 mm in diameter*), the whorl gradually becomes again somewhat high turreted, occuping about one and a half or two volutions, with a consequent, proportionately smaller umbilicus. The whorls of this stage are just touching, the ribs of neighbouring whorls being in gear, or slightly separated, and followed by the body whorl. The body whorl at first follows the coiling of the phragmocone for about one-third to a half volution, and then breaks away rather abruptly from the spire, forming a large C-shaped hook suspended below the spire. Although the body chamber is deformed in some degree in most specimens, it is slightly higher than broad in section, with the aperture facing obliquely upward to the base of the spire.

The shell is ornamented with numerous radial ribs and two rows of tubercles, except for the preserved first, nearly smooth whorl with the diameter of about 4 mm, which is

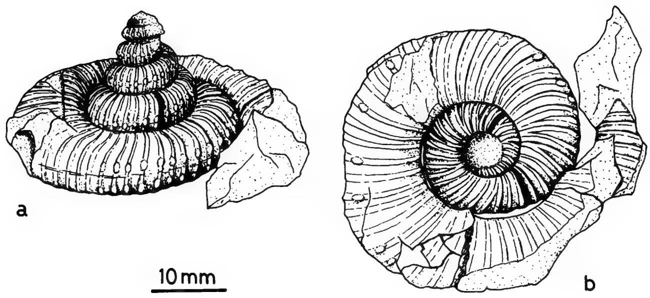

Fig. 9. *Didymoceras awajiense* (YABE).
Diagramatic sketch of a immature shell, TN820620-2, showing upper lateral (a) and basal (b) views.

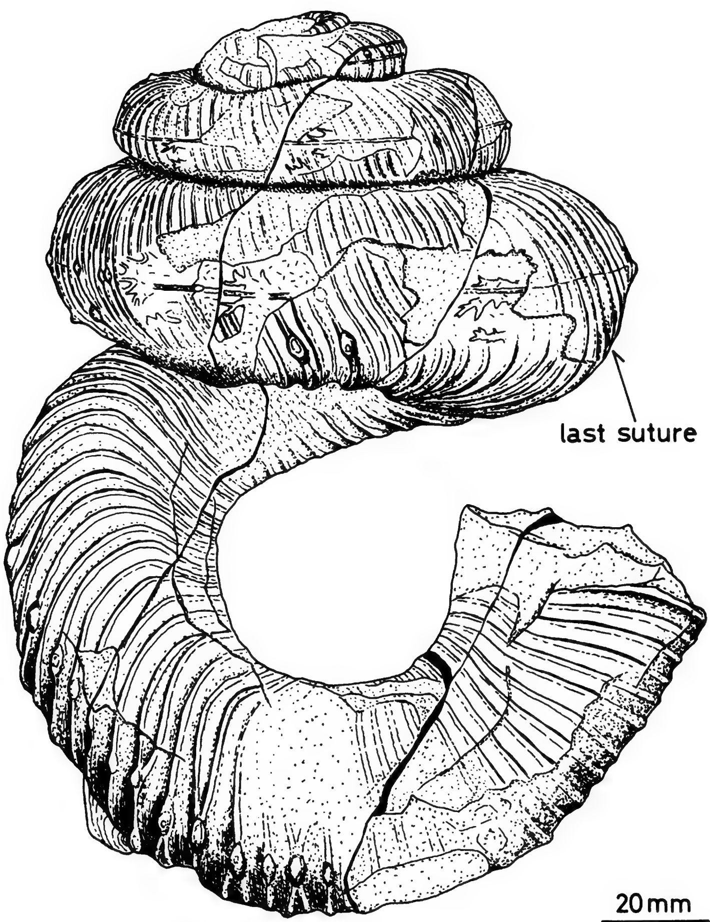

Fig. 10. *Didymoceras awajiense* (YABE).
Diagramatic sketch of OMNH. M2211, showing a lateral view.

observable in one specimen, TN820620-1. The ribs are sharp, separated by wider interspaces, and rather simple on the main part of the shell, though the bifurcation and intercalation become to occur fairly frequently at or near the lower (basal) ventrolateral shoulder of the whorl as the shell grows; they are gently sinuous, forming a broad backward curve on the upper flank and a forward curve on the lower flank, crossing the external side (i.e. the venter) slightly obliquely, and then running almost radially around the umbilicus; they are rather finer and weaker on the internal (i.e. umbilical) side. The ribs are numerous and dense on the main part of the helical whorls, numbering 10 to 14 within the interval as large as the whorl breadth (or height), whereas they are rather coarse in young stages, numbering about 4 in early growth stage and 5 to 8 in middle growth stage within the same interval. They also become coarser on the body chamber, being 6 to 8 in number within the same interval.

The tubercles in two rows appear on all ribs in early stage, on every second rib in pair in middle stage, and rather irregularly on every second to fourth rib, sometimes on every fifth or sixth, in pair or alternately on the rest of the septate whorl. The tubercles of the upper row are situated on the mid-line of the external surface, i.e. on or near the siphuncle, and those of the lower row are on the ventrolateral shoulder, though embraced in most part by the later whorl. On the body chamber they become again frequent, occurring finally at every rib on the last limb. They are bullate and shortly spinose at the top, some of them being large and nodose on the last limb of the body chamber.

Shallow constrictions occur irregularly, being associated with flared ribs, the last one of which is discernible near the aperture.

The suture is finely and deeply incised with E, L, U and probably I, leaving narrowed stems. The first lateral saddle (E/L) is larger than the second one (L/U), and L is fairly deeper than E and probably than U, all the observable elements being bifid.

Variation: There is significant variation in mode of coiling, which greatly influences the height of the spire and the diameter of the spiral whorl. One of the specimen examined (TN01; pl. 10, fig. 4), though not adult, has a extremely low spire, coiling almost planispirally up to the diameter of 90 mm or so. If it lived longer, it might have much larger diameter of the last spiral whorl over 110 mm. On the other hand, two specimens (OMNH. M2212; pl. 14, fig. 1 and SN04; pl. 13, fig. 2) have fairly high turreted spire, with a relatively small diameter of about 90 mm, the coiling of which is not so planispiral but somewhat helical even in middle growth stage. Examples of normal coiling are represented by OMNH. M2211 (pl. 11, fig. 1), MS06 (pl. 15, fig. 2), MS07 (pl. 13, fig. 1), MS11 (pl. 12, fig. 1) and many others, which have rather low spire with almost planispiral middle stage. A transitional form between normally coiled specimens and high turreted ones is represented by MS10 (pl. 12, fig. 2). Thus, the individual with less developed planispiral stage has a tendency to show taller appearance with smaller diameter. Of 29 specimens examined, 18 are dextral, the rest 11 being sinistral.

Despite the significant variation in mode of coiling, the ribbing is fairly constant in the

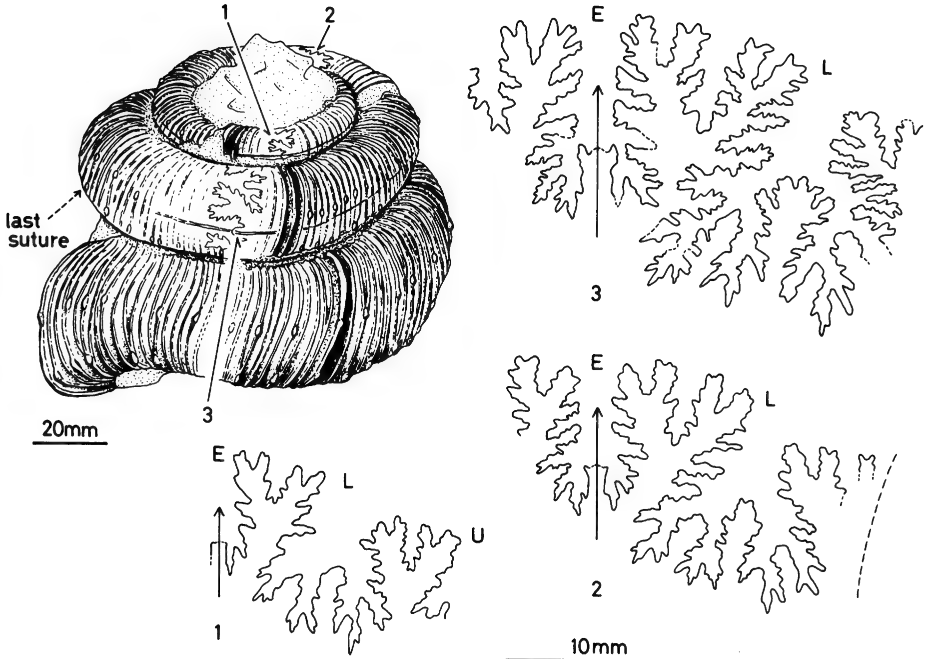

Fig. 11. *Didymoceras awajiense* (YABE).
Diagramatic sketch of MS07, showing a lateral view and sutures.

examined specimens, although two of them (OMNH. M2212 and MS10) have somewhat coarser ribs on the body chamber than many others. The tubercles vary in strength, frequency and position with growth and also among individuals, but are seen in any stage of growth. The tubercles of the upper row are generally situated on the marginal siphuncle, but they tend to shift slightly upward from the siphonal zone at the portion where the whorl is almost planispiral, and slightly downward at the relatively high turreted portions. This may be closely related to the change in living posture. Both ribs and tubercles are also variable in intensity due to condition of preservation of the test. If the outer shell layer is not preserved, being frequently broken away through the cleaning of fossils, the ribs appear low and round-topped with interspaces as wide as them, and the tubercles can be seen as faint node-like elevations. On the internal mould, the tubercles are hardly discernible.

It is notable that many of smaller specimens without retroversal hook do not represent the preserved earlier parts of adult shells but represent young shells, because they are provided with body whorl of that stage. They seem to have died in youth.

Discussion: The rather lengthy description above is to show the variation in *Didymoceras awajiense*. MATSUMOTO (1977a, p. 323) and MATSUMOTO *et al.* (1981b, p. 175) have suggested that there may be more than one species in the so-called "*D. awajiense*"

from the Izumi Group. It is indeed true that there is another distinct species of *Didymoceras*, which is not yet described, in the unit underlying the *D. awajiense* Zone in Shikoku, but I am inclined to conclude that the specimens from Awaji described above are to be included within the variation of the same species.

D. awajiense is closely allied to *Pravitoceras sigmoidale* YABE from the overlying zone of the Izumi Group in Awaji and Shikoku (MATSUMOTO *et al.*, 1981b, p. 169; pl. 22, fig. 1; pl. 23, figs. 1-2; pl. 24, figs. 1-3; pl. 25, figs. 1-2; pl. 26, fig. 1; text-figs. 1-2) in having similar ornamentation and similar, almost undistinguishable mode of coiling in young stages, with turreted shell in early stage followed by almost planispiral whorls in the succeeding stage. As MATSUMOTO *et al.* (1981b, p. 175) have discussed, *P. sigmoidale* is possibly evolved from *D. awajiense*, by lowering the helical phragmocone and then obtaining nearly planispiral coiling even in later growth stages up to the retroversally hooked body whorl. In the morphological point of view, varieties of the present species which have nearly planispiral middle stage for rather long duration, as is characteristically reprsented by TN01 (pl. 10, fig. 4), seem to be most intimately related to *P. sigmoidale*.

In having rather low spire, relatively high turreted forms of *D. awajiense* as represented by OMNH. M2212 and SN04 resemble *Didymoceras hornbyense* (WHITEAVES) from the Upper Lambert Formation (Upper Campanian) in Hornby Island, British Columbia (Usher, 1952, p. 103; pl. 27, figs. 1-2; pl. 28, fig. 2; pl. 31, fig. 23). But *D. hornbyense* has gradually separated spiral whorls which grade into the body chamber, and has coarser ribs in early mature stage.

Didymoceras depressum sanctaeluciense KLINGER (1976, p. 65; pl. 25, figs. 1-3; pl. 26, figs. 1-3; pl. 27, figs. 1-2; pl. 28, figs. 1-4; pl. 29, figs. 1-3; pl. 30, figs. 1-2; text-fig. 8f-h) from the St. Lucia Formation (Upper Campanian) of Zululand has some resemblance to *D. awajiense*, especially to forms with very low spire. Zululand species, however, has a larger diameter of the last spiral whorl, tightly coiled later whorls with a distinct contact furrow and a body whorl which breaks away abruptly from the low spire without rather high turreted stage.

Didymoceras nakaminatoense (SAITO, 1958, p. 91; pl. 5, figs. 1-2) from the Nakaminato Formation (middle part) of the Naka Group in Ibaraki Prefecture, about 100 km northeast of Tokyo, is fairly different from *D. awajiense* in having rapidly enlarging whorls, a proportionately smaller spire in contrast with large hook of the body chamber and the suture with shallower E and deeper I.

Occurrence: "Minato Shale" of the Seidan Formation. This species is also found from the Izumi Group in Naruto area, northeastern Shikoku and from the Toyajo Formation of the Sotoizumi Group in Kii Peninsula. Several specimens described by SAITO (1958) as *Nostoceras awajiense* (YABE) from the Nakaminato Formation (middle part) of the Naka Group are probably assigned to the present species, although they are rather small in size.

Genus *Nostoceras* HYATT, 1894

Type species: *Nostoceras stantoni retrosum* HYATT (= *N. stantoni* HYATT, emend. STEPHENSON, 1941), designated by HYATT (1894).

Discussion: This genus is characterized by a closely coiled spire followed by a U-shaped retroversal body chamber that breaks away suddenly from the spire, as STEPHENSON (1941, P. 407) and HOWARTH (1965, p. 374) redefined.

MATSUMOTO (1977a, p. 322) considered that *Nostoceras* was probably descended from *Didymoceras*. Indeed, there are some species which show intermediate features between the two genera, having closely coiled spire and looped, instead of U-shaped, not elongated body chamber, as represented by *Nostoceras colubriformis* STEPHENSON (1941, p. 412; pl. 81, figs. 1-3) or *N. rotundum* HOWARTH (1965, p. 381; pl. 10, fig. 3). They had better be included in *Didymoceras* rather than *Nostoceras*.

Nostoceras hetonaiense MATSUMOTO
Pl. 16, figs. 1-5; Pl. 17, figs. 5-6

1977. *Nostoceras hetonaiense* MATSUMOTO, *Mem. Fac. Sci., Kyushu Univ., Ser. D (Geol.)* 23(3): 322; pl. 54, fig. 2; pl. 55, fig. 1.

cf. 1980. *Nostoceras* sp. B aff. *N. hetonaiense* MATSUMOTO: MATSUMOTO and MOROZUMI, *Bull. Osaka Mus. Nat. Hist.* (33): 17; pl. 14, fig. 1.

Holotype: GK.H5798a, from loc. H1091p, Lower Sandy Siltstone of the Hakobuchi Group in the Tomiuchi area, southern central Hokkaido.

Material: Six specimens of incomplete preservation; OMNH. M2209 (coll. by M. SATO), MT02, MT193, TN81076 (body chamber only), TN81078 (two volutions of a spire) and MT136 (a part of a spire), all from loc. Aw14 (Mitsugawa). SN02 and OMNH. M2192 (coll. by Y. MOROZUMI), both from loc. Aw12 (Chikusa), and SN03 from loc. Aw13 (Kake-ooji) are also referable to this species.

Description: The shell consists of a low spire and a elongated, U-shaped body chamber which breaks away from the spire at about the last septum. The spire has more than two, dextrally or sinistrally coiled whorls which are just touching each other, the diameter of the last whorl being about 45 mm with the exception of one small example (SN02: D= 36.6 mm). The shell of the intial stage is not preserved in any specimen.

On the spiral whorl the ribs are fine and numerous, numbering about 14 in the distance as long as the whorl-breadth (B). Two rows of tubercles are developed at irregular intervals; they are at every third to fifth rib on the last whorl of many specimens. Tubercles of the lower row are generally more numerous and more pronounced than those of the upper row. The mode of tuberculation, however, varies by specimens and by positions of the whorl. The ribs are rather simple, but bifurcation occurs frequently at the tubercles.

On the body chamber the ribs become a little coarser, being about 10 in number per B. On the earlier shaft and the curved portion of U, the intercalation and bifurcation of ribs occur rather frequently, and the tubercles are nodose, being generally disposed

alternately at every second to fourth rib. On the last shaft the ribs become simple, and tiny spinose tubercles are disposed on each rib near the aperture. The intensity and frequency of tubercles on the body chamber also vary by specimens.

Discussion: Most specimens from Awaji have been more or less deformed and are fragmentary. However, the shell size and the mode of observable ornamentaion coinside well with those of the holotype of *Nostoceras hetonaiense* MATSUMOTO (1977a, p. 322; pl. 54, fig. 2; pl. 55, fig. 1) from the Lower Sandy Siltstone of the Hakobuchi Group (probable Lower Maastrichtian) in the Tomiuchi area, Hokkaido.

MATSUMOTO (1977a) mentioned that the diameter of the last spiral whorl of this species was about 55-60 mm. But the body chamber of the holotype (GK.H5798a) has been discrepantly disposed at the point where it breaks away from the spire. If restored, the diameter will be somewhat smaller, probably being about 45 mm at the last septum.

Occurrence: This species occurs in northern muddy facies of the Kita-ama Formation. At Mitsugawa (loc. Aw14) and Kake-ooji (loc. Aw13) this species is characteristically accompanied by *Inoceramus* (*Endocostea*) *shikotanensis*.

Genus *Pravitoceras* YABE, 1902

Type species: *Pravitoceras sigmoidale* YABE, 1902 (original designation).

Pravitoceras sigmoidale YABE
Pl. 18, figs. 1-2

1902. *Pravitoceras sigmoidale* YABE, *Jour. Geol. Soc. Tokyo* 9: 6; pl. 1, figs. 2-4.
1915. *Pravitoceras sigmoidale* YABE: YABE, *Sci. Rep. Tohoku Imp. Univ., 2nd Ser.* 4(1): 19; pl. 2, figs. 1-4; pl. 3, fig. 1.
1981. *Pravitoceras sigmoidale* YABE: MATSUMOTO, MOROZUMI, BANDO, HASHIMOTO and MATSUOKA, *Trans. Proc. Palaeont. Soc. Japan, N. S.* (123): 169; pl. 22, fig. 1; pl. 23, figs. 1-2; pl. 24, figs. 1-3; pl. 25, figs. 1-2; pl. 26, fig. 1; text-figs. 1, 3.

Material: Single specimen; KI01 from loc. Aw2 (Minakuchi).

Discussion: *Pravitoceras sigmoidale* has recently been redescribed in detail by MATSUMOTO *et al.* (1981b), based on many, fairly well preserved specimens from Awaji Island and Naruto erea in Shukoku. Therefore, I do not intend to repeat the description of this species, but give some comments on the variation in size.

According to MATSUMOTO *et al.* (1981b), there exist some variation in size of this species. The length of a S-shaped shell is normally 225-240 mm and about 290 mm in larger examples. A exceptionally small specimen, measuring 184 mm in length of S, was interpreted to be a dwarf individual. At the same time, an unusually large specimen from the Toyajo Formation of the Sotoizumi Group, which had been illustrated by YABE (1915, pl. 3, fig. 1) as an example of *P. sigmoidale,* was regarded as a probable coiled part of *Diplomoceras* sp., because no tubercle was observed on that specimen.

Now, the present specimen is extremely large for this species, the length of S-form being 365 mm and the diameter of the coiled part being about 190 mm at the last septum.

It is also notable that the tubercles in two rows of the present specimen are very faintly prominent at irregular intervals. Thus, the shell size and the intensity of the tubercles show a great extent of variation in *P. sigmoidale*. From this fact, the above-mentioned large specimen from the Toyajo Formation may be included within the variation of this species, although careful reexamination of that specimen is needed.

Occurrence: "Minato Shale" of the Seidan Formation.

Genus *Solenoceras* CONRAD, 1860

Type species: *Hamites annulifer* MORTON, 1842 (original disignation).

Discussion: Diagnosis of this genus has been defined by WRIGHT (1957, p. L224) and KLINGER (1976, p. 77). Due to the discovery of fairly well preserved specimens of *Solenoceras humei* (DOUVILLÉ) by LEWY (1967, p. 169; pl. 3, figs. 1-3), it was clarified that *Solenoceras* shows a gyroconic spire at the early ontogenetic stage. *Solenoceras* is now accepted as a member of Nostoceratidae.

Majority of authors (e.g. STEPHENSON, 1941, p. 398; WRIGHT, 1957, p. L224; LEWY, 1967, p. 169; KLINGER, 1976, p. 77; WARD and MALLORY, 1977, p. 608) regarded *Oxybeloceras* HYATT, 1900 as a synonym of *Solenoceras*, whereas SPATH (1953, p. 16) and MATSUMOTO (1959c, p. 162) maintained *Oxybeloceras*. *Oxybeloceras* is generally somewhat larger than *Solenoceras* and has no perceptible constriction, although the shell form and the ornamentation are similar to each other. On this account, MATSUMOTO and MOROZUMI (1980, p. 20) treated *Oxybeloceras* as a subgenus of *Solenoceras*, whom I follow in this paper. Phylogenetic relation between *Solenoceras* and *Pseudoxybeloceras* has been discussed by WARD and MALLORY (1977, p. 616-617) and MATSUMOTO and MOROZUMI (1980, p. 20).

Subgenus *Solenoceras* CONRAD, 1860

Solenoceras (*Solenoceras*) sp. cf. *S.* (*S.*) *texanum* (SHUMARD)
Pl. 17, figs. 1-3

cf. 1941. *Solenoceras texanum* (SHUMARD): STEPHENSON, *Univ. Texas Publ.* (4101): 399; pl. 77, figs. 4-5; pl. 79, figs. 1-4.
? 1969. *Solenoceras* cf. *texanum* (SHUMARD): LEWY, *Israel Jour. Earth Sci.* 18: 127; pl. 8, fig. 8.
cf. 1976. *Solenoceras* cf. *texanum* (SHUMARD): KLINGER, *Geol. Surv. South Africa, Mem.* 69: 77; pl. 34, fig. 7.

Material: Three specimen; TN820620, TN830514 and OMNH.M2210 (coll. by M. SATO), all from loc. Aw2 (Minakuchi).

Description: Each specimen consists of slender, slightly curved two shafts which are 25 to 30 mm long and touch each other. The young shaft, with circular sectin, is embraced in the dorsum of the last shaft. The shell of early gyroconic stage and of apertural part is not preserved in any specimen.

The ornaments of the young shaft consist of distantly spaced constrictions and weak

ribs. They are somewhat prorsiradiate and comparatively well pronounced on the ventrolateral part. Each rib bears a pair of small tubercles.

The surface of the last shaft is ornamented with sharp and simple ribs which are somewhat coarse, about 4 within the distance of height, rather rursiradiate, becoming progressively rectiradiate toward the U-curved portion, and separated by wider interspaces.

The mode of tuberculation on the last shaft and the suture are not observable.

Discussion: Due to poor preservation of Awaji specimens, the above observation is insufficient for the precise comparison. But, the observed characters agree well with those of *Solenoceras texanum* (SHUMARD) from the Navarro Group of Texas (STEPHENSON, 1941, p. 399; pl. 77, figs. 4-5; pl. 79, figs. 1-4), although the specimens from Awaji are a little more slender.

The present specimens are similar to the examples of *S. reesidei* STEPHENSON (1941, p. 401; pl. 77, figs. 1-3) from the Navarro Group, but are different in their coarser ribs on the last shaft and weaker ribs on the young shaft.

Occurrence: "Minato Shale" of the Seidan Formation; *Pravitoceras sigmoidale* Zone.

Subgenus *Oxybeloceras* HYATT, 1900

Type species: *Ptychoceras crassum* WHITFIELD, 1800 (original designation).

Solenoceras (*Oxybeloceras*) sp. aff. *S.* (*O.*) *humei* (DOUVILLÉ)
Pl. 17, fig. 4

cf. 1928. *Ptychoceras humei* DOUVILLÉ, *Mém. Acad. Sci. Inst. France* 60: 37; pl. 6, figs. 9-10.
cf. 1967. *Solenoceras humei humei* (DOUVILLÉ): LEWY, *Israel Jour. Earth Sci.* 16: 171; pl. 3, figs. 1-3.

Material: Single specimen; OMNH.M2177-3, coll. by A. MATSUOKA, from loc. Aw6 (Minato).

Description: The specimen is incomplete and the shell of early growth stage and of apertural part is not preserved, but consists of two shafts which are not in contact with each other. Only one side of it is developed from the rock. The preserved young shaft is 34 mm long and slightly curved, and the last one is almost straight with length of about 20 mm.

The shell is ornamented with sharp-headed simple ribs; they are somewhat coarse, about 4 to 5 within the distance of height, rather prorsiradiate on the young shaft, nearly rectiradiate on the U-curved part and slightly rursiradiate on the last shaft, becoming gradually rectiradiate toward the apertural part. The ribs show some weakening on the venter and the dorsum.

Each rib on both shafts bears a pair of small spinose tubercles at the ventrolateral shoulders. There is no perceptible constriction.

Discussion: This specimen has some resemblance to the representatives of *Solenoceras humei humei* (DOUVILLÉ) from the Upper Campanian of Israel (LEWY, 1967, pl. 3, figs.

1-3) in having non-constricted large shell and sharp-headed simple ribs. In that species, however, the ribs are somewhat more crowded and the two shafts are in contact, though leaving an "almond-like" empty space inside the curved portion.

Probably this specimen reprensents a new species of *Solenoceras* (*Oxybeloceras*) which is allied to *S.* (*O.*) *humei*, but it is too poor to establish a new species.

Occurrence: "Minato Shale" of the Seidan Formation. The present specimen was embeded in one nodule together with a few shells of *Pravitoceras sigmoidale*.

Family Baculitidae MEEK, 1876

Genus *Baculites* LAMARCK, 1799

Type species: *Baculites vertebralis* DEFRANCE, 1830 (designated by MEEK, 1876).

Baculites inornatus MEEK

1862. *Baculites inornatus* MEEK, *Proc. Acad. Nat. Sci., Philad.* 13: 316.
1959. *Baculites inornatus* MEEK: MATSUMOTO, *Mem. Fac. Sci., Kyushu Univ., Ser. D* (*Geol.*) 8 (4): 155; pl. 38, fig. 1; pl. 43, fig. 5; text-figs. 72-79.
1963. *Baculites inornatus* MEEK: OBATA and MATSUMOTO, *Ibid.* 13 (1): 78; pl. 22, fig. 1; pl. 24, fig. 6; pl. 26, figs. 4-6; text-figs. 169, 170, 187-190.
1978. *Baculites inornatus* MEEK: WARD, *Jour. Paleont.* 52 (5): 1151; pl. 1, figs. 1-2; text-fig. 5.

Lectotype: NSNM.1259, one of the MEEK's original specimens, designated by MATSUMOTO (1959b), from "Sucia Island, Washington".

Discussion: This species from Awaji was described by OBATA and MATSUMOTO (1963) based on a large number of specimens, some of which I have also examined. No material of subsequent collection is available for me. Although most specimens from Awaji were incomplete internal moulds, OBATA and MATSUMOTO (1963) clearly showed the sutures with phylloid terminations of *B. inornatus* type.

Occurrence: Fine sandy siltstone of the Seidan Formation at Nagata (loc. Aw7) and mudstone of the Kita-ama Formation at Okubo (loc. Aw10) and Tokuhara (loc. Aw11); *Pachydiscus awajiensis* Zone.

Affinity of ammonite faunas of Awaji Island

Twenty ammonite species were discriminated from the Izumi Group in Awaji Island, as shown in Table 2. Among nine well defined species, *Pachydiscus* (*P.*) *awajiensis* n. sp. and *Patagiosites laevis* n. sp. are particular to Awaji Island, and *Pravitoceras sigmoidale* is restricted within Southwest Japan.

Ammonite faunas of Awaji are closely allied to those of Hokkaido. The elements of the faunas at family and also generic levels are similar to those of the Hetonaian (approximately Campanian and Maastrichtian) of Hokkaido (MATSUMOTO, 1954; MATSUMOTO *et al.*, 1980b; MATSUMOTO and MIYAUCHI, 1984), the following species being common to both areas; *Hypophylloceras* (*Neophylloceras*) *hetonaiense* MATSUMOTO, *Gaudryceras izumiense* MATSUMOTO and MOROZUMI, *Anagaudryceras matsumotoi* n. sp., *Zelandites* cf. *varuna* (FORBES), *Nostoceras hetonaiense* MATSUMOTO and *Baculites inornatus* MEEK. In addition to these species, several species from Awaji are closely related to those from Hokkaido and Sakhalin; *Pachydiscus* (*P.*) *awajiensis* is close to *P.* (*P.*) *excelsus* MATSUMOTO, *Pachydiscus* (*P.*) aff. *subcompressus* is to *P.* (*P.*) *subcompressus* MATSUMOTO, *Patagiosites laevis* is to *P. compressus* MATSUMOTO and *Gaudryceras* aff. *striatum* is to *G. striatum* (JIMBO).

The faunas of Awaji have some resemblance to those from the Campanian - Maastrichtian of southern Alaska (Matanuska Formation), Vancouver Island (Nanaimo Group) and southern India (Ariyalur Group), although only a few species are common to both Awaji and these areas (JONES, 1963; USHER, 1952; WARD, 1978; FORBES, 1846; STOLICZKA, 1864-66; KOSSMAT, 1895-98). *H. (Neophylloceras) hetonaiense* occurs also in Alsaka and Vancouver Island, and *Baculites inornatus* in Vancouver Island. *Patagiosites laevis* is close to *P. alaskensis* JONES, and *Vertebrites* cf. *kayei* and *Zelandites* cf. *varuna* are probably identical with the species from India. The fewness of common species between the areas in question may be explained mainly by a concept of faunal provincialism within the northern Indo-Pacific province, but partly by some difference in age between the fossiliferous formations.

There is little relationship between the faunas of Awaji and those of Europe, Madagascar, Gulf Coast and Western Interior of North America, without common species except for widely distributed *Solenoceras* (*S.*) *texanum* (SHUMARD), which has been also recorded from Texas (STEPHENSON, 1941), Israel (LEWY, 1969) and Zululand (KLINGER, 1976).

Intra-Japanese correlation of ammonite faunas

1. Position of the Awaji faunas in the biostratigraphy of the Izumi Group

The Izumi Group shows a characteristic geologic structure that generally forms a synclinorium with an eastward plunge. Due to this structure, which is considered to have

been caused by the eastward stepwise shift of the sedimentary basin (ICHIKAWA *et al.*, 1981), the fossiliferous beds certainly become younger towards the east (SUYARI, 1973; MATSUMOTO and MOROZUMI, 1980; MATSUMOTO *et al.*, 1981b). This implies that we can easily grasp the ammonite succession of the Izumi Group by examining records of ammonites from the west to the east, although the ammonite localities are distributed intermittently.

The westernmost (the lowest) locality is Dogo-Himezuka near Matsuyama, where *Gaudryceras striatum* (JIMBO) is associated with *Sphenoceramus schmidti* (MICHAEL) (NODA and TASHIRO, 1973). At about 40 km east of Matsuyama, there is a locality (Hotokezaki, Saijo City) of *Bevahites* aff. *lapparenti* COLLIGNON with *Sph.* cf. *schmidti* (MATSUMOTO and OBATA, 1963). Further eastward from the above two localities, there are several localities with *Metaplacenticeras subtilistriatum* (JIMBO) on the northern base of the Asan Mountains (MATSUMOTO *et al.*, 1980a, 1981b; personal communication of Mr. J. MIYAMOTO), which are followed by three localities (Gesho, Takeyashiki and Dogadaira) with *Baculites kotanii* MATSUMOTO, HASHIMOTO and FURUICHI (MATSUMOTO *et al.*, 1980a) and then by a locality (Kanewari) with *Didymoceras* sp. (undescribed species) (Fig. 12).

Despite the separation of the distributional area of the Izumi Group by the Straits of Naruto, both the *Didymoceras awajiense* Zone and the overlying *Pravitoceras sigmoidale* Zone can be traced from Awaji to the Naruto area, northeastern part of Shikoku, where there are several localities with *D. awajiense* and with *P. sigmoidale* (MATSUMOTO *et al.*, 1981a). In Shikoku, the *D. awajiense*-bearing beds are also stratigraphically lower than the *Pravitoceras*-bearing part. They are, however, of fairly higher level than the localities of *Metaplacenticeras subtilistriatum.*

In the Izumi Mountains, MATSUMOTO and MOROZUMI (1980) recognized nine ammonite localities and sorted them into two main horizons, A2 (the lower) and B5 (the upper); A2 is reprenented by such well-known localities as Azenotani and Takinoike, and B5 by Sobura. Horizon A2 is characterized by *Pachydiscus* (*P.*) *kobayashii* (SHIMIZU), *Canadoceras tanii* MATSUMOTO and MOROZUMI, *Nostoceras* aff. *hetonaiense* MATSUMOTO and *Baculites regina* OBATA and MATSUMOTO, whereas Horizon B5 by *Pachydiscus* (*P.*) aff. *flexuosus* MATSUMOTO, *P.* (*Neodesmoceras*) cf. *gracilis* MATSUMOTO, *Gaudryceras izumiense* MATSUMOTO and MOROZUMI, *Nostoceras* aff. *kernense* (ANDERSON) and *Hoploscaphites* (?) sp. As only a few species are common to both Awaji and the Izumi Mountains, zonal correlation of the Izumi Group in both areas is not easy. However, the upper two zones defined in Awaji, the *Nostoceras hetonaiense* and *Pachydiscus* aff. *subcompressus* Zones, should be traced to the western part of the Izumi Mountains, judging from the general geologic structure of the Izumi Group, although the Izumi Group seems to have been considerably displaced by probable faults at the Straits of Kitan. Horizon A2 may be assigned to part of the *N. hetonaiense* Zone, whereas Horizon B5 to or somewhere near the *P.* aff. *subcompressus* Zone. *Gaudryceras izumiense* occurs abundantly in B5 and rarely in A2 in the Izumi Mountains. Recent discovery of *Zelandites* cf. *varuna* from Sansaka

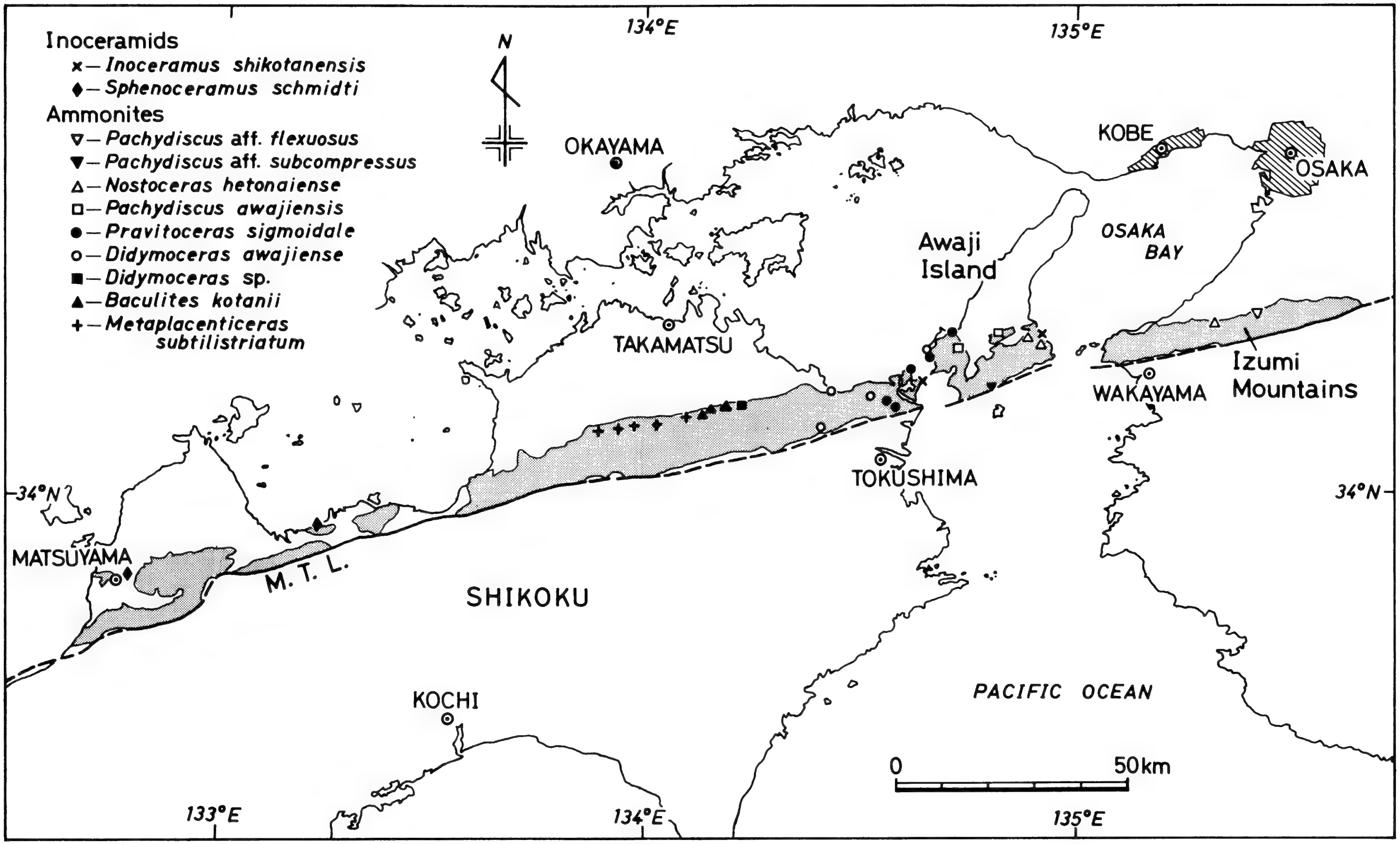

Fig. 12. Map showing selected fossil localities of the Izumi Group with zonal indices. Dotted area indicates the distribution of the Izumi Group. M.T.L.: Median Tectonic Line.

(Horizon B3) also supplement the above correlation.

Fossils are rather scarce in the eastern part of the Izumi Mountains. However, some fragmentary ammonites have been obtained from a locality (Hashiramoto, Hashimoto City) (personal communication of Mr. K. YAMAMOTO). Recently, IMIYA (1984) discovered some Middle Maastrichtian planktonic foraminifers including *Globigerinelloides sosebudensis*. The Izumi Group is still of the Cretaceous even at the eastern extremity of the Izumi Mountains.

The ammonite succession of the Izumi Group discussed above is summarized in Figs. 12 and 13.

2. Correlation with the zonation in Hokkaido

MATSUMOTO (1977b; 1981) has proposed a revised scheme of zonation for the Upper Cretaceous of Hokkaido based on inoceramids and ammonites. He then divided the Hetonaian into five substages, i.e. K6a1, K6a2, K6a3, K6b1 and K6b2 in ascending order, K6a being approximately correlated with the Campanian and K6b with the Maastrichtian. Each substage is represested by a inocerami zone and a few ammonite zones with zonal indices and associated species, although ammonite zonation has not yet been established to our satisfaction.

Now, among the proposed ammonite zones in Awaji Island, the *Nostoceras hetonaiense* Zone is easily assignable to K6b1, as it contains *N. hetonaiense* and *Inoceramus* (*Endocostea*) *shikotanensis* NAGAO and MATSUMOTO, both of which are indices of K6b1 in Hokkaido. The overlying *Pachydiscus* aff. *subcompressus* Zone is probably assigned to K6b2, judging from the characteristic occurrence of *"Inoceramus" awajiensis* MATSUMOTO, although some elements of the fauna of this zone such as *Anagaudryceras matsumotoi* n. sp. and *Zelandites* cf. *varuna* are also occur in K6b1 of Hokkaido.

On the other hand, the lower three zones in Awaji, i.e. the *Didymoceras awajiense, Pravitoceras sigmoidale* and *Pachydiscus awajiensis* Zones, are not easily correlated with those in Hokkaido, because most ammonite species in them have not yet been known from Hokkaido.

In Hokkaido, the Zone of *Metaplacenticeras subtilistriatum* [K6a3] overlies the Zone of *Sphenoceramus schmidti*-*Canadoceras kossmati* [K6a2] at some places in the Teshio Mountains, in the Soya area and also in the Urakawa area (MATSUMOTO, 1982b; MATSUMOTO *in* MATSUMOTO and MIYAUCHI, 1984), but the zones above it can not be known in these areas because of the lack of exposures. It is not, however, recognized in other areas, e.g. the Tomiuchi area (MATSUMOTO, 1942-43; 1954; 1977a), type area of the Hetonaian, the Tombetsu Valley (MATSUMOTO *et al.*, 1980b; 1981a) and the Nemuro area (KIMINAMI, 1978; MATSUMOTO and YOSHIDA, 1979), where the Zone of *S. schmidti*-*C. kossmati* is overlain by some intervening beds of non- or poorly fossiliferous facies and then by the Zone of *I.* (*E.*) *shikotanensis*-*Pachydiscus* (*Neodesmoceras*) *japonicus* [K6b1]. In other words, there is a barren interval without ammonite and inceramid between the

Lower Hetonaian [K6a] and the Upper Hetonaian [K6b] in Hokkaido.

In the Izumi Belt, however, it is undoubted that the *Didymoceras awajiense* Zone is stratigraphically fairly higher than the beds with *Metaplacenticeras subtilistriatum*, as mentioned in the preceding pages. SUYARI (1973) recorded *Inoceramus* (*Endocostea*) *shikotanensis* at a locality facing the Naruto Strait. This locality stratigraphically lies at about 1500 m above the *Pravitoceras*-bearing beds in Shikoku. This horizon nearly corresponds to the base of the Kita-ama Formation in Awaji Island, i.e. the middle part of the *Pachydiscus awajiensis* Zone. Thus, the *P. awajiensis* Zone may be partly correlated with the Zone of *I.* (*E.*) *shikotanensis* [K6b1] in Hokkaido, though *I.* (*E.*) *shikotanensis* has not yet been known from the *P. awajiensis* Zone in Awaji. This correlation may be supported by the occurrence of *"Anisomyon" problematicus* NAGAO and OTATUME from this zone, since this species generally accompanies *I.* (*E.*) *shikotanensis* in Hokkaido. Another possibility is that *I.* (*E.*) *shikotanensis* may have a longer range extending downward to the Lower Hetonaian [K6a]. This may be supported by the occurrence of *Baculites inornatus* MEEK from the *P. awajiensis* Zone, since *B. inornatus* commonly occurs in the lower part of the Zone of *Metaplacenticeras subtilistriatum* [K6a3] in the Soya area of Hokkaido (MATSUMOTO and MIYAUCHI, 1984). The stratigraphic ranges of both *I.* (*E.*) *shikotanensis* and *B. inornatus* should be studied more carefully.

Anyhow, the Zones of *Didymoceras awajiense, Pravitoceras sigmoidale* and *Pachydiscus awajiensis* have not yet been recognized from Hokkaido. They represent the zones between the *Metaplacenticeras subtilistriatum* Zone and the *I.* (*E.*) *shikotanensis* Zone, leaving a possibility that the *P. awajiensis* Zone may be partly included in the *I.* (*E.*) *shikotanensis* Zone.

International correlation and age assignment

Although the Campanian/Maastrichtian boundary in Europe is still a matter of dispute, JELETZKY (1951)'s interpretation, which places the boundary between the *Belemnella lanceolata* Zone and the *Belemnitella mucronata minor* Zone, is generally accepted by the majority of authors (JONES, 1963; HENDERSON, 1970; HOWARTH, 1965; COBBAN, 1974; CHRISTENSEN 1975; etc.). According to this interpretation, the boundary nearly corresponds to that between the *Bostrychoceras polyplocum* Zone and the *Pachydiscus neubergicus* Zone, and the Upper Campanian is characterized by many species of *Pachydiscus, Hoplitoplacenticeras, Didymoceras* and others, and the Maastrichtian by *Hoploscaphites constrictus, Acanthoscaphites tridens, Diplomoceras cylindraceum, Baculites vertebralis, Pachydiscus neubergicus, P. gollevillensis, P. colligatus* and species of *Sphenodiscus* (e.g. BIRKELUND, 1979; RAWSON *et al.*, 1978; HANCOCK and KENNEDY, 1981). However, as none of the ammonites from the Izumi Group is specifically identical with those from the Campanian and the Maastrichtian in Europe, the proposed zones can be only indirectly correlated with the international scale.

The species of typical *Didymoceras,* which *D. awajiense* resembles, occur characteristically in the Upper Campanian. In Europe, "*Bostrychoceras*" *polyplocum* (RÖMER) represents a next upper zone above the *Hoplitoplacenticeras vari* Zone (JELETZKY, 1951). *Hoplitoplacenticeras* is a good index of the Upper Campanian, the majority of species of this genus occuring in the lower part of the Upper Campanian in various regions of the world (JELETZKY, 1951; COBBAN, 1963; HOWARTH, 1965; MATSUMOTO, 1982a). In British Columbia, WARD (1978a) revised the biostratigraphy of the Nanaimo Group and divided the Upper Campaian into three zones, i.e. the *Hoplitoplacenticeras vancouverense, Mataplacenticeras pacificum* and *Pachydiscus suciaensis* Zones in ascending order, although the last might extend to the Lower Maastrichtian. He then put the *Didymoceras hornbyense* Zonule in the *P. suciaensis* Zone at the top of the Campanian. In the Western Interior of North America, the Zones of *D. nebrascense, D. stevensoni* and *D. cheyennense* have their positions at 14th, 15th and 17th respectively of 22 zones settled in the Campanian (GILL and COBBAN, 1973). KLINGER (1976) described *D. depressum sanctaeluciense* from the Campanian IV & V Zone, next lower zone below the Maastrichtian I Zone, in Zululand. In the Izumi Group, as the *D. awajiense* Zone is of higher level than the *Metaplacenticeras subtilistriatum* Zone, which has been assigned to the lower part of the Upper Campanian (MATSUMOTO, 1982a, b; MATSUMOTO *in* MATSUMOTO and MIYAUCHI, 1984), it is assigned to the upper part of the Upper Campanian.

The ages of the *Pravitoceras sigmoidale* Zone and the overlying *Pachydiscus awajiensis* Zone are not easily determined, because these zones lack ammonite species useful for correlation. *P. sigmoidale* and *P. awajiensis* are both endemic. Among the concurrent species, *Solenoceras* (*S.*) *texanum*, comparable species of which occur in the *P. sigmoidale* Zone, has been described from the Neylandville Marl and the Nacatoch Sand of the Navarro Group in Texas (STEPHENSON, 1941). These formations were regarded as the Maastrichtian by STEPHENSON (1941), but HOWARTH (1965, p. 409) suggested late Campanian age to them. Probable this species has been also recorded from the Upper Campanian of Israel (LEWY, 1969) and of Zululand (KLINGER, 1976).

The occurrence of *Baculites inornatus* from the *P. awajiensis* Zone in noteworthy, since it is common in a subzone immediately below the prolific part of *Metaplacenticeras subtilistriatum* in Hokkaido (MATSUMOTO and MIYAUCHI, 1984) and below the Zone of *M. pacificum* in Vancouver Island, Britith Columbia (WARD, 1978a). However, it has not yet been known from the Maastrichtian. On the whole, I am inclined to include both zones in the Upper Campanian.

The *Nostoceras hetonaiense* Zone contains only *N. hetonaiense* and a species of *Nostoceras*, and age assignment of this zone is also difficult.

From the probable correlative of this zone in the Izumi Mountains, MATSUMOTO and MOROZUMI (1980) recorded *Neophylloceras hetonaiense, Pachydiscus* (*P.*) *kobayashii, Canadoceras tanii* and certain heteromorph species of *Nostoceras, Solenoceras, Pseudoxybeloceras, Diplomoceras, Baculites* and others, and then suggested an age of latest

Campanian or early Maastrichtian for this fauna but avoided to determine either of the two alternatives. MATSUMOTO (1959d; 1977b; etc.) has regarded *Inoceramus* (*Endocostea*) *shikotanensis* and *Pachydiscus* (*Neodesmoceras*) *japonicus* from K6b1 of Hokkaido as zonal indices of the Lower Maastrichtian in Japan. K6b1 of Hokkaido surely contains some ammonites which are also common in K6b2 (unmistakable Maastrichtian) such as *Anagaudryceras matsumotoi* and *Zelandites* cf. *varuna* (MATSUMOTO, 1954; MATSUMOTO *et al.*, 1980b), although these species are not sufficient as the direct evidence of Maastrichtian age. For the present, the *Nostoceras hetonaiense* Zone in Awaji is tentatively assigned to the Lower Maastrichtian.

The *Pachydiscus* aff. *subcompressus* Zone is most probably assigned to the Lower Maastrichtian. As MATSUMOTO (*in* MATSUMOTO *et al.*, 1979, p. 53) has pointed out, *P.* (*P.*)

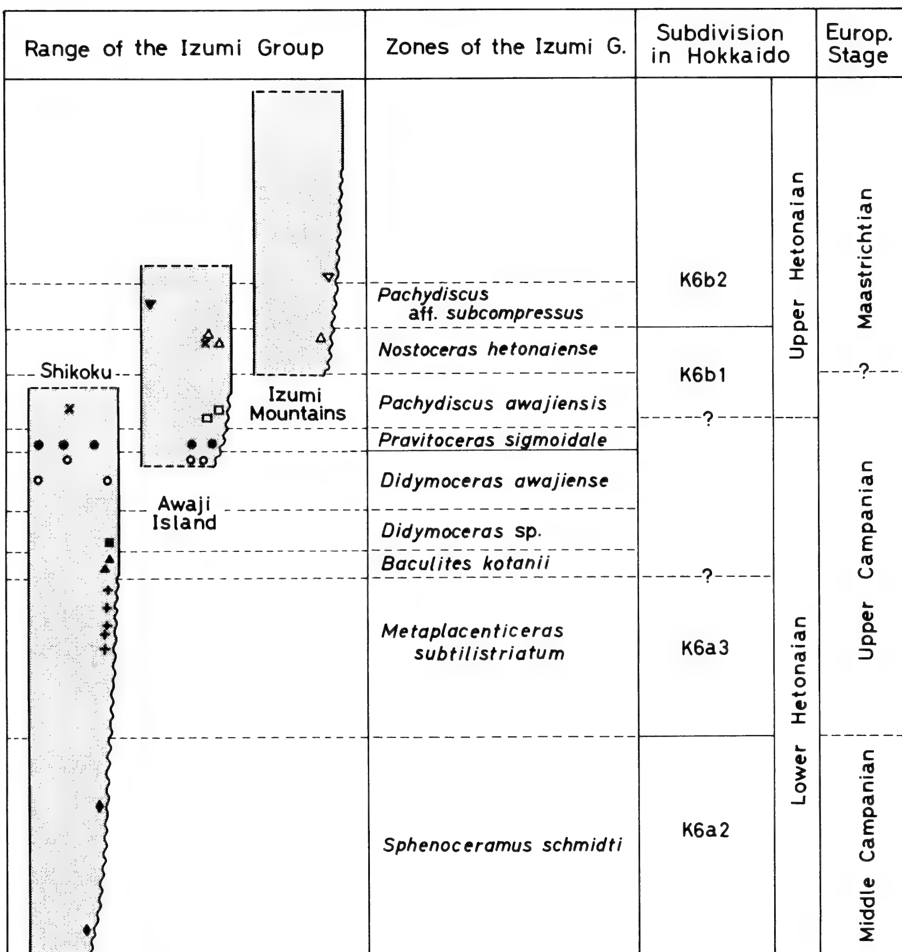

Fig. 13. Biostratigraphic correlation of the Izumi Group.
The stratigraphic positions of zonal indices are indicated in the left column. The marks are the same as in Fig. 12.

subcompressus MATSUMOTO must be a northern Pacific counterpart of *P.* (*P.*) *gollevillensis* (D'ORBIGNY) from the Lower Maastrichtian of Europe, Madagascar and other areas, to both species *P.* (*P.*) aff. *subcompressus* being closely allied. Moreover, this zone contains two species which are probably identical with *Vertebrites kayei* (FORBES) and *Zelandites varuna* (FORBES) described from the Varudayur Formation of India. Besides the above two species, such ammonites of Maastrichtian aspect as *Pachydiscus egertoni* (FORBES), *P.* sp. aff. *gollevillensis* and *Sphenodiscus siva* (FORBES) have been also recorded from that formation (FORBES, 1846; KOSSMAT, 1895-98).

To sum up, the Campanian/Maastrichtian boundary in Awaji Island is tentatively drawn at the zonal boundary between the *P. awajiensis* Zone and the *N. hetonaiense* Zone. Recently BŁASZKIEWICZ (1966; 1980) established the Campanian and Maastrichtian biostratigraphy in Poland, and recognized four ammonite zones in the Upper Campanian and two in the Lower Maastrichtian. He divides the former *Bostrychoceras polyplocum* Zone into two zones, the *B. polyplocum* Zone (below) and the *Didymoceras donezianum* Zone (above), and places the *Nostoceras pozaryskii* Zone still higher as the top zone in the Upper Campanian. The ammonite succession in Awaji seems to be in good harmony with that in Poland.

Anyhow, the base data of zonal indices of the Maastrichtian in Europe such as *Belemnella lanceolata, Pachydiscus neubergicus* and *Hoploscaphites constrictus* never seem to show the precise synchronization. Their stratigraphic relationships could be resolved with the aid of microfossils such as planktonic foraminifers and coccoliths, which would generally give a finer resolution. The Campanian/Maastrichtian boundary in Awaji could be examined in another way by further studies of microfossils.

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Kuroiwa 黒岩, Matsuyama 松山, Midori-cho 緑町, Mihara-gun 三原郡, Minakuchi 水口, Minato 湊, Mitsugawa 三ツ川, Nada 灘, Nagata 長田, Naka 那珂, Nakaminato 那珂湊, Nakamura 中村, Nakano 仲野, Nandan-cho 南淡町, Naruto 鳴門, Nemuro 根室, Okubo 大久保, Ryugase 龍ケ瀬, Saijo 西条, Sansaka 山坂, Seidan-cho 西淡町, Sennan 泉南, Senposhi 仏鳳趾, Shichi 志知, Shikoku 四国, Shimanto 四万十, Shimonada 下灘, Sobura 蕎原, Sotoizumi 外和泉, Soya 宗谷, Sumoto 洲本, Takeyashiki 竹屋敷, Takinoike 滝ノ池, Teshio 天塩, Tokuhara 徳原, Tombetsu 頓別, Tomiuchi 富内, Toyajo 鳥屋城, Tsui 津井, Uchihara 内原, Urakawa 浦河, Yamamoto 山本, Yezo エゾ

淡路島産の後期白亜紀（カンパニアン〜マストリヒチアン）アンモナイト

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日本の最上部白亜系（カンパニアン階〜マストリヒチアン階）はヘトナイ統で代表されるが，北海道の模式地では粗粒な堆積物が卓越することもあって，そのアンモナイト層序は下位の諸階に比べて必ずしも十分に解明されているとはいえない。このことが，白亜紀末における生物地理区分化の進行，ヨーロッパの標準地域におけるカンパニアン階〜マストリヒチアン階境界問題と関連し，ヘトナイ統の厳密な国際対比をむずかしくする一因ともなっている。一方，西南日本の和泉層群には，カンパニアン階中部からマストリヒチアン階にわたり，北海道での資料の不足を補う興味あるフォーナが認められる。ここでのアンモナイト層序を確立するため，地理的にも生層序学的にも和泉山脈と四国の和泉層群の中間にあたって，両者を結ぶ重要な位置を占める淡路島の和泉層群を選び，その層序を再検討するとともに，同層群産アンモナイトを研究し，次の成果を得た。

淡路島の和泉層群は，北縁相（西淡累層）•主部相（下位より阿那賀累層，北阿万累層および灘累層）•南部相（下灘累層）に分けられる。西淡累層は種々の層位を示す基底礫岩とその上位の厚い泥岩層からなる。主部相の各累層は，タービダイトを主体とする砂岩・礫岩・泥岩の律動的な互層からなり，岩相の側方変化が著しい。北縁相の細砂質シルト岩および主部相の北縁に近い泥岩が優勢な部分からは，比較的豊富に化石が産出する。下灘累層は白色砂岩および細砂質シルト岩からなる。淡路島の南端に断層で画されて分布するため，北側の和泉層群との層序関係は不明だが，含まれる化石から，北阿万累層あるいは灘累層の一部に対比されると考えた。

淡路島の和泉層群からは，17地点から20種のアンモナイトが識別された。これらのうち，*Pachydiscus awajiensis, Patagiosites laevis, Anagaudryceras matsumotoi* の3新種を含む18種を記載・図示した。また，*Didymoceras awajiense* (YABE) を再定義し，変異を含めて詳しく再記載を行った。淡路島産のアンモナイト・フォーナは，北海道のヘトナイ統のフォーナとの類縁が深く，多くの共通種や近似種を含む反面，地域差も認められる。また，北米太平洋岸地域や南インドの同時代または近い時代のフォーナとの類縁性もわずかではあるが指摘される。

特徴種の層序的分布に基づき，淡路島の和泉層群は下位より *Didymoceras awajiense* 帯，*Pravitoceras sigmoidale* 帯，*Pachydiscus awajiensis* 帯，*Nostoceras hetonaiense* 帯および *Pachydiscus* aff. *subcompressus* 帯に分帯される。これらのうち，*N. hetonaiense* 帯と *P.* aff. *subcompressus* 帯は，それぞれ北海道のヘトナイ統上部階の下部（K6b1）と同上部（K6b2）に相当し，ほぼマトリヒチアン階に対比される。それに対し，*D. awajiense* 帯，*P. sigmoidale* 帯および *P. awajiensis* 帯の3帯は北海道では認められていない。これら3帯は，北海道のヘトナイ統下部階の上部（K6a3）の指標種である *Metaplacenticeras subtilistriatum* の四国における産出層位より明らかに上位にあたることから，K6a3 と K6b1 の間の亜階を代表し，カンパニアン階上部の上半に対比されると考えた。

日本からは，ヨーロッパにおけるマストリヒチアン階の指標種が全く産出しないので，淡路島におけるカンパニアン階／マストリヒチアン階境界は厳密には決められないが，本論では *P. awajiensis* 帯と *N. hetonaiense* 帯の境界に引くことを提案した。

Explanation of Plate 1

Figs. 1-5. *Hypophylloceras* (*Neophylloceras*) *hetonaiense* MATSUMOTO

1 . GK. H6886, 2 . GK. H6884, 3 . GK. H6885 and 5 . GK. H6888; all from loc. Aw15 (Haraikawa), Shimonada Formation, × 1 .

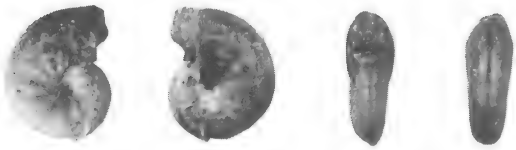
4 . OMNH. M2208, loc. Awl (Kiba), "Minato Shale", Seidan Formation, × 1 .

Fig. 6. *Hypophylloceras* (*Neophylloceras*) sp. aff. *H.* (*N.*) *mikobokense* (COLLIGNON)

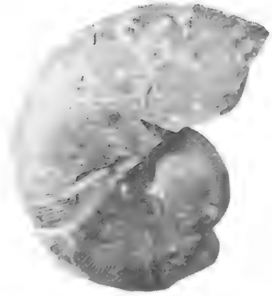
OMNH. M2190, fragmentary septate whorl, loc. Aw7 (Nagata), Seidan Formation.
Lateral view (a) and natural whorl section (b), × 1 .

Fig. 7. *Pachydiscus* sp.

OMNH. M2189, internal mould, loc. Aw9 (Kemuri-jima), Kita-ama Formation, × 1 .



1a 1b 1c 1d



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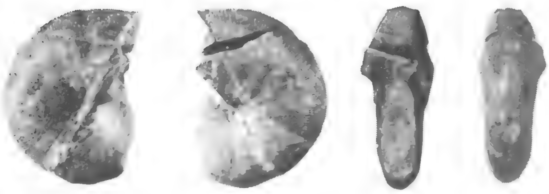
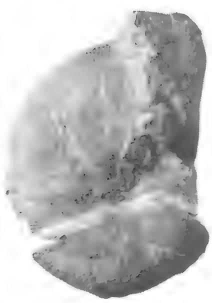


2a 2b 2c 2d



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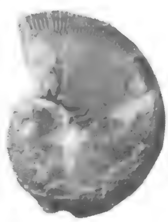


4

7a

6a 6b 7b

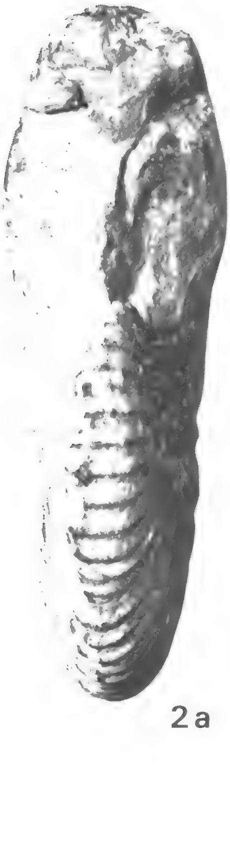
Explanation of Plate 2

Figs. 1-2. *Pachydiscus* (*Pachydiscus*) *awajiensis* MOROZUMI, n. sp.

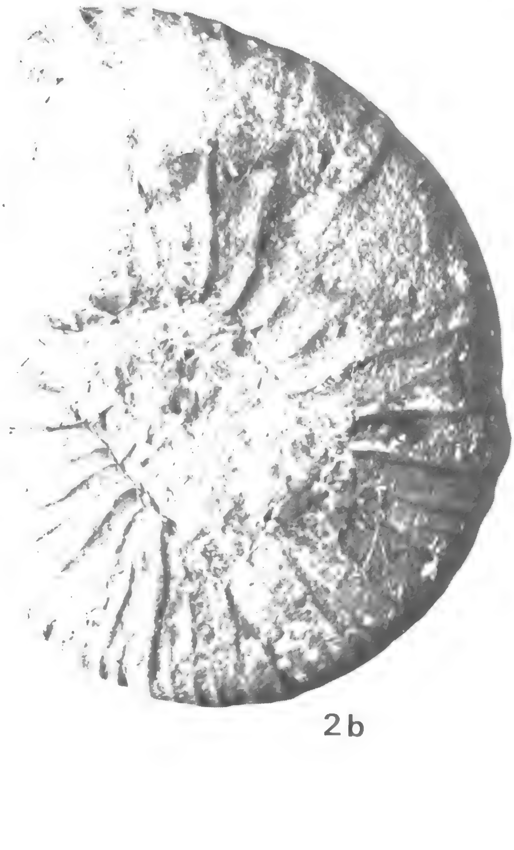
1. OMNH. M2205, holotype, loc. Aw7 (Nagata), Seidan Formation. Lateral (a) and ventral (b) views, × 3/4. See also Pl. 3, fig. 2.
2. KS830417, paratype, loc. Aw7 (Nagata), Seidan Formation. Frontal (a), lateral (b) and ventral (c) views, × 3/4.

1a

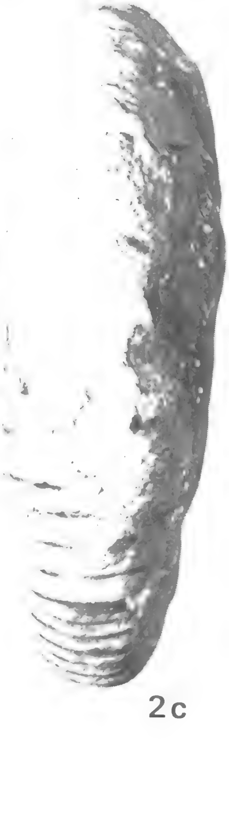
1b



2a



2b



2c

Explanation of Plate 3

Figs. 1–2. *Pachydiscus* (*Pachydiscus*) *awajiensis* MOROZUMI, n. sp.

1. OMNH. M2216, paratype, loc. Aw7 (Nagata), Seidan Formation. Lateral (a) and frontal (b) views, × 2/3.
2. Lateral view of OMNH. M2205, holotype, loc. Aw7 (Nagata), Seidan Formation, × 2/3. See also Pl. 2, fig. 1 (the outer whorl excluded in Pl. 2, fig. 1 is added here).

1a

1b

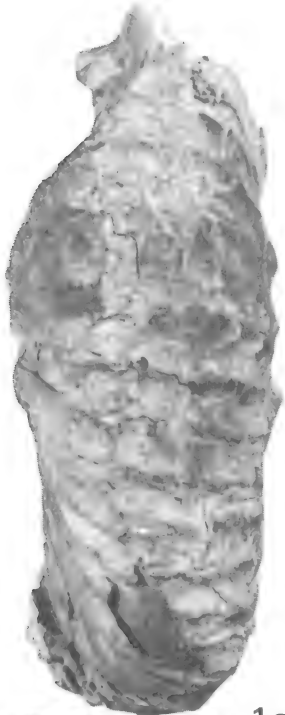
2

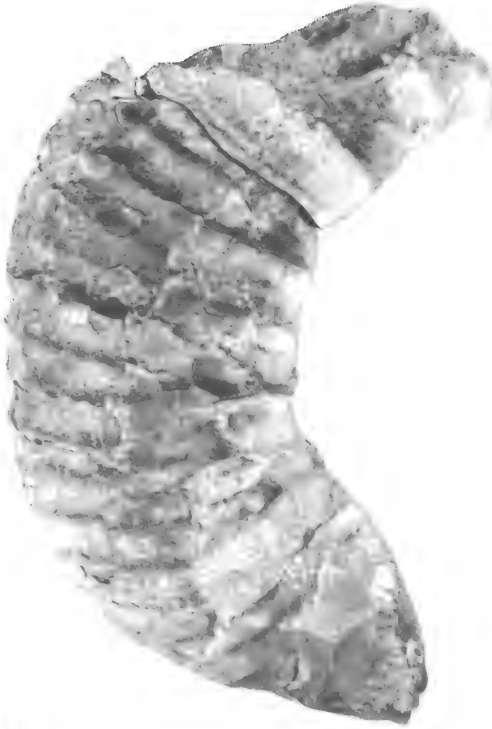
Explanation of Plate 4

Fig. 1. *Pachydiscus* (*Pachydiscus*) sp. cf. *P.* (*P.*) *awajiensis* MOROZUMI
OCU. MM341, fragmentary internal mould of septate whorl, loc. Aw8 (Hanzanji), "Shichi Shale", Anaga Formation.
Ventral (a) and lateral (b) views, × 3/4.

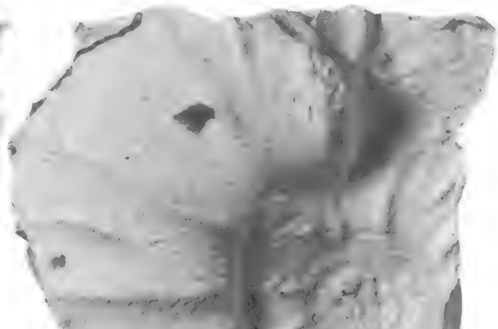
Fig. 2. *Pachydiscus* (*Pachydiscus*) *awajiensis* MOROZUMI, n. sp.
Lateral view of OMNH. M2199, paratype, imcomplete body chamber, loc. Aw7 (Nagata), Seidan Formation, × 2/3.

Fig. 3. *Pachydiscus* (*Pachydiscus*) sp. aff. *P.* (*P.*) *awajiensis* MOROZUMI
GK. H9305, gypsum copy taken from the external cast, THS442-855, loc. Aw8 (Hanzanji), "Shichi Shale", Anaga Formation, × 3/4.


1a

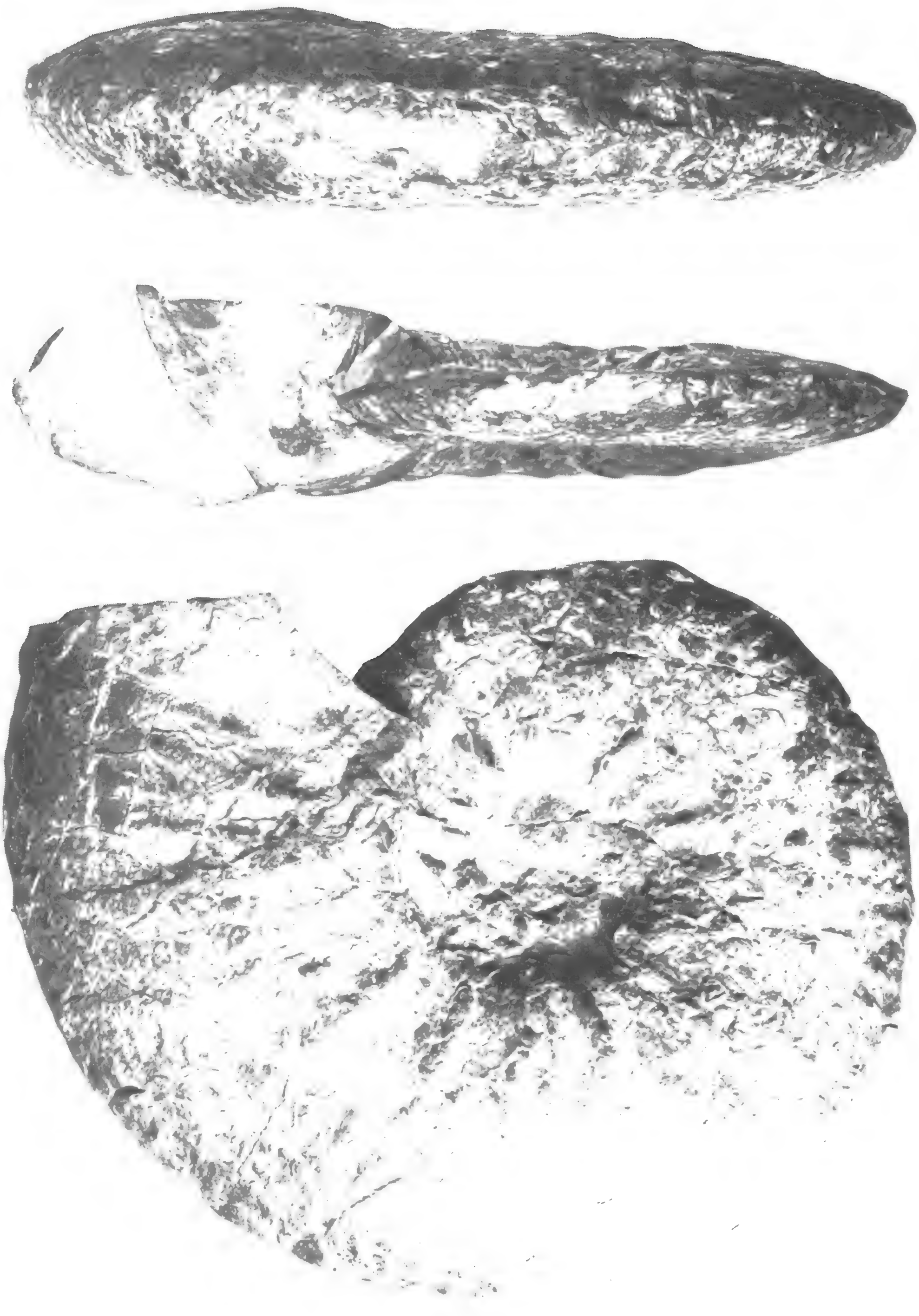

1b


2


3

Explanation of Plate 5

Fig. 1. *Pachydiscus* (*Pachydiscus*) sp. aff. *P.* (*P.*) *subcompressus* MATSUMOTO
GK. H6883, loc. Aw16 (Yamamoto), Shimonada Formation.
Lateral (a), frontal (b) and ventral (c) views, × 2/3. See also Pl. 7, fig. 1 for another lateral view.



1c

1b

1a

Explanation of Plate 6

Fig. 1. *Patagiosites laevis* MOROZUMI, n. sp.
JM386, holotype, internal mould, loc. Aw1 (Kiba), "Minato Shale", Seidan Formation. Lateral (a), ventral (b) and frontal (c) views, × 2/3.

1c

1b

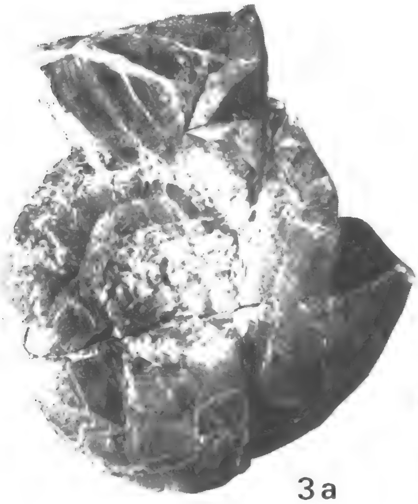
1a

Explanation of Plate 7

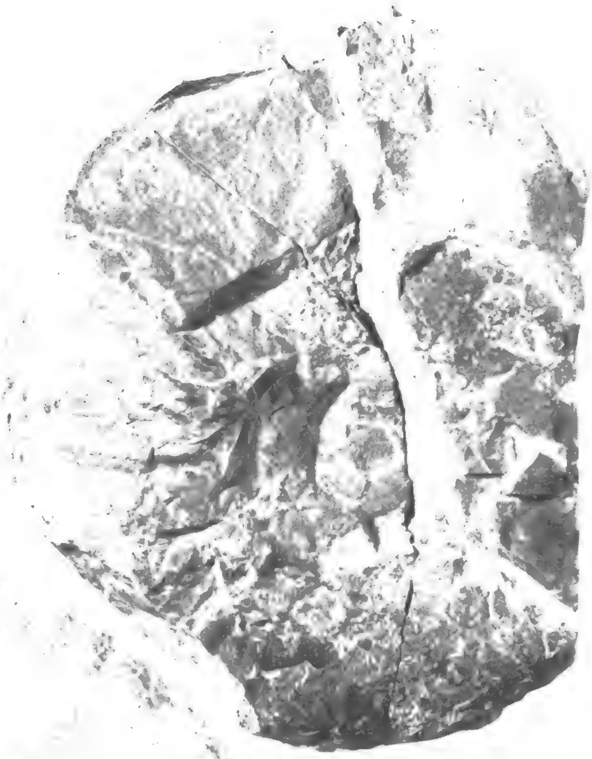
Fig. 1. *Pachydiscus* (*Pachydiscus*) sp. aff. *P.* (*P.*) *subcompressus* MATSUMOTO
Lateral view of GK. H6883, loc. Aw16 (Yamamoto), Shimonada Formation, × 2/3.
See also Pl. 5 for the other views.

Fig. 2. *Patagiosites laevis* MOROZUMI, n. sp.
Lateral view of SN01, paratype, loc. Aw1 (Kiba), "Minato Shale", Seidan Formation, × 2/3.

Fig. 3. *Saghalinites* (?) sp.
OCU. MM353, loc. Aw15 (Haraikawa), Shimonada Formation.
Lateral (a) and frontal (b) views, × 1 .

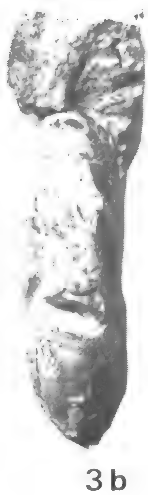


3a



2

1



3b

Explanation of Plate 8

Fig. 1. *Gaudryceras* sp. aff. *G. striatum* (JIMBO)
OMNH.M2200, fragmentary septate whorl, loc. Awl (Kida), "Minato Shale", Seidan Formation. Natural whorl section (a) and lateral view (b), × 2/3.

Fig. 2. *Gaudryceras izumiense* MATSUMOTO and MOROZUMI
Lateral view of MT01, compressed internal mould, loc. Aw17 (Kuroiwa), Shimonada Formation, × 2/3.

1a

2

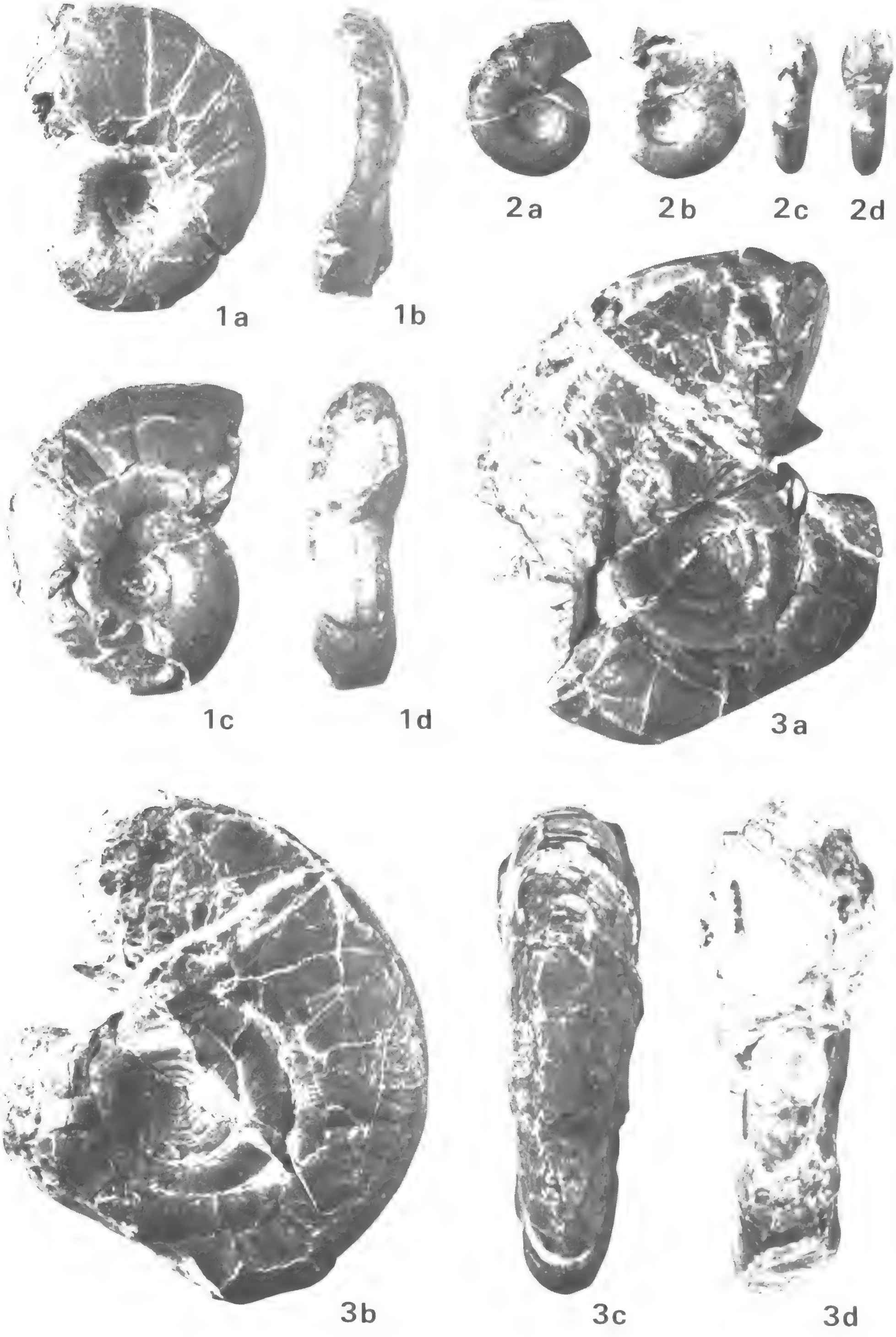
1b

Explanation of Plate 9

Fig. 1. *Anagaudryceras matsumotoi* MOROZUMI, n. sp.
GK.H6882, holotype, loc. Aw15 (Haraikawa), Shimonada Formation. Two lateral (a, c), ventral (b) and frontal (d) views, × 1.

Fig. 2. *Zelandites* sp. cf. *Z. varuna* (FORBES)
OCU.MM352, loc. Aw15 (Haraikawa), Shimonada Formation. Two lateral (a, b), ventral (c) and frontal (d) views, × 1.

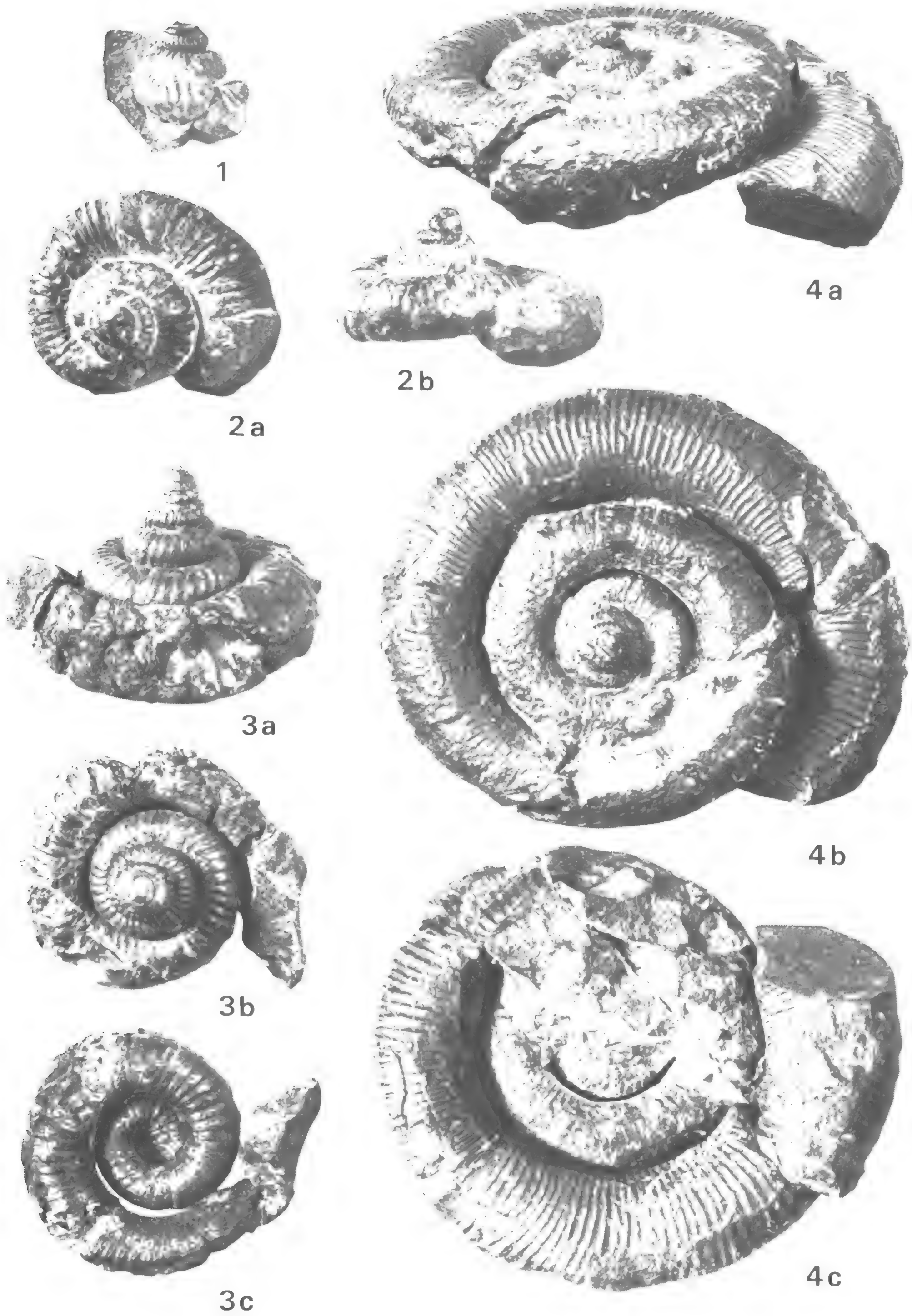
Fig. 3. *Vertebrites* (?) sp. cf. *V. kayei* (FORBES)
OCU.MM351, loc. Aw15 (Haraikawa), Shimonada Formation. Two lateral (a, b), ventral (c) and frontal (d) views, × 1.


1a
1b
2a
2b
2c
2d
1c
1d
3a
3b
3c
3d

Explanation of Plate 10

Figs. 1–4. *Didymocers awajiense* (YABE)

1. TN820620-1, 2. KI02 and 3. TN820620-2; immature specimens with fairly well preserved shell of early growth stage, all from loc. Awl (Kiba), "Minato Shale", Seidan Formation.
   Lateral (1, 2b, 3a), apical (2a, 3b) and basal (3c) views, × 1.
4. TN01, middle-aged shell with very low spire, loc. Aw1 (Kiba), Seidan Formation.
   Lateral (a), apical (b) and basal (c) views, × 3/4.


1
2a
2b
3a
3b
3c
4a
4b
4c

Explanation of Plate 11

Fig. 1. *Didymoceras awajiense* (YABE)

Three lateral views of OMNH.M2211, fairly well preserved, typical adult shell, loc. Aw1 (Kiba), "Minato Shale", Seidan Formation, × 2/3.

1a

1b

1c

Explanation of Plate 12

Figs. 1–2. *Didymoceras awajiense* (YABE)

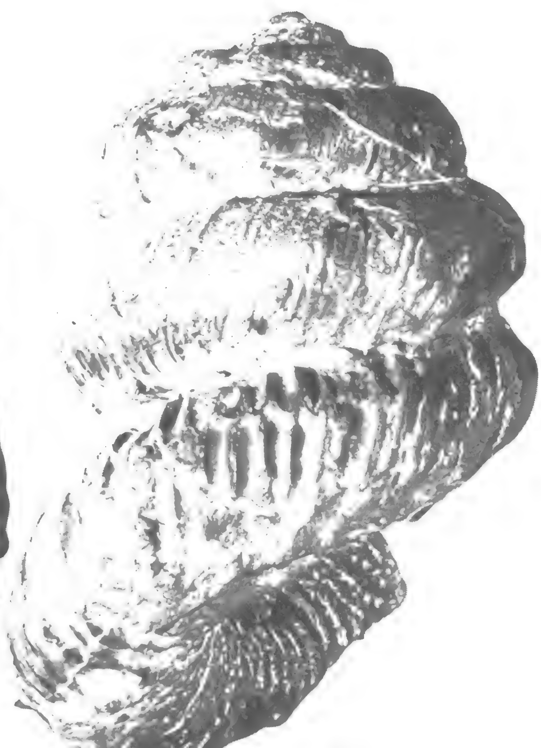
1. Two lateral views of MS11, somewhat small shell, × 2/3.
2. Two lateral views of MS10, example with somewhat high turreted spire and rather coarsely ribbed body whorl, × 2/3.

Both specimens from loc. Aw1 (Kiba), "Minato Shale", Seidan Formation.

1a

1b

2a



2b

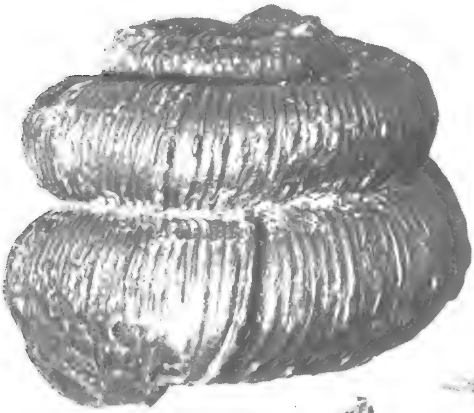
Explanation of Plate 13

Fig. 1-2. *Didymoceras awajiense* (YABE)

1 . MS07, specimen without retroversal hook. Lateral (a), apical (b) and basal (c) views, × 2/3.

2 . Two lateral views of SN04, example with fairly high turreted spire, × 2/3.

Both specimens from loc. Aw1 (Kiba), "Minato Shale", Seidan Formation.



1a

1b

1c

2a

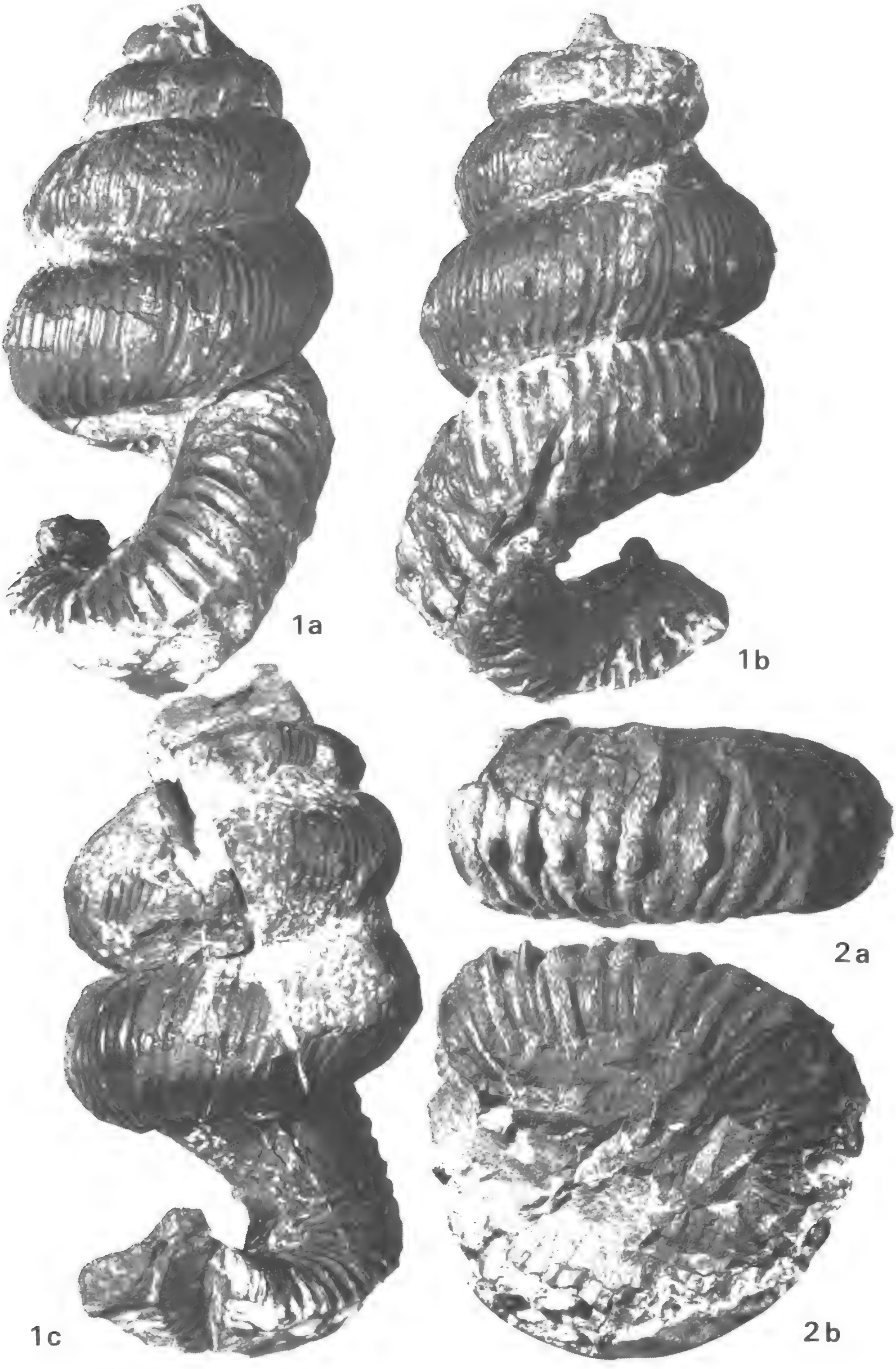
2b

Explanation of Plate 14

Figs. 1-2. *Didymoceras awajiense* (YABE)

1. OMNH. M2212, example with fairly high turreted spire and rather coarsely ribbed body whorl. Three lateral views, × 2/3.
2. OMNH. M2213, part of body whorl with large node-like tubercles, × 2/3.

Both specimens from loc. Aw1 (Kiba), "Minato Shale", Seidan Formation.


1a
1b
1c
2a
2b

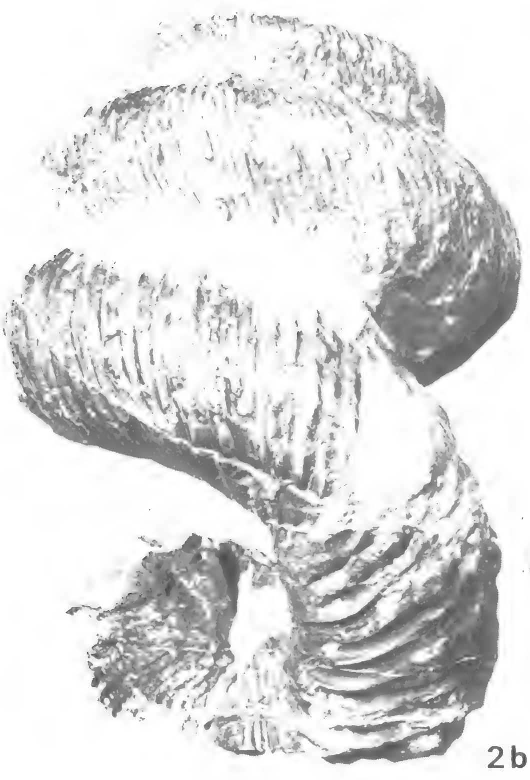
Explanation of Plate 15

Figs. 1–3. *Didymoceras awajiense* (YABE)

1. MT709, somewhat small shell with rather separated spiral whorls, loc. Aw1 (Kiba), "Minato Shale", Seidan Formation, × 2/3.
2. Two lateral views of MS06, loc. Aw1 (Kiba), × 2/3.
3. Lateral view of GH.NM.Na-04, somewhat high turreted spire, loc. Aw3 (Nakano), "Minato Shale", Seidan Formation, × 2/3.

1

2a



2b

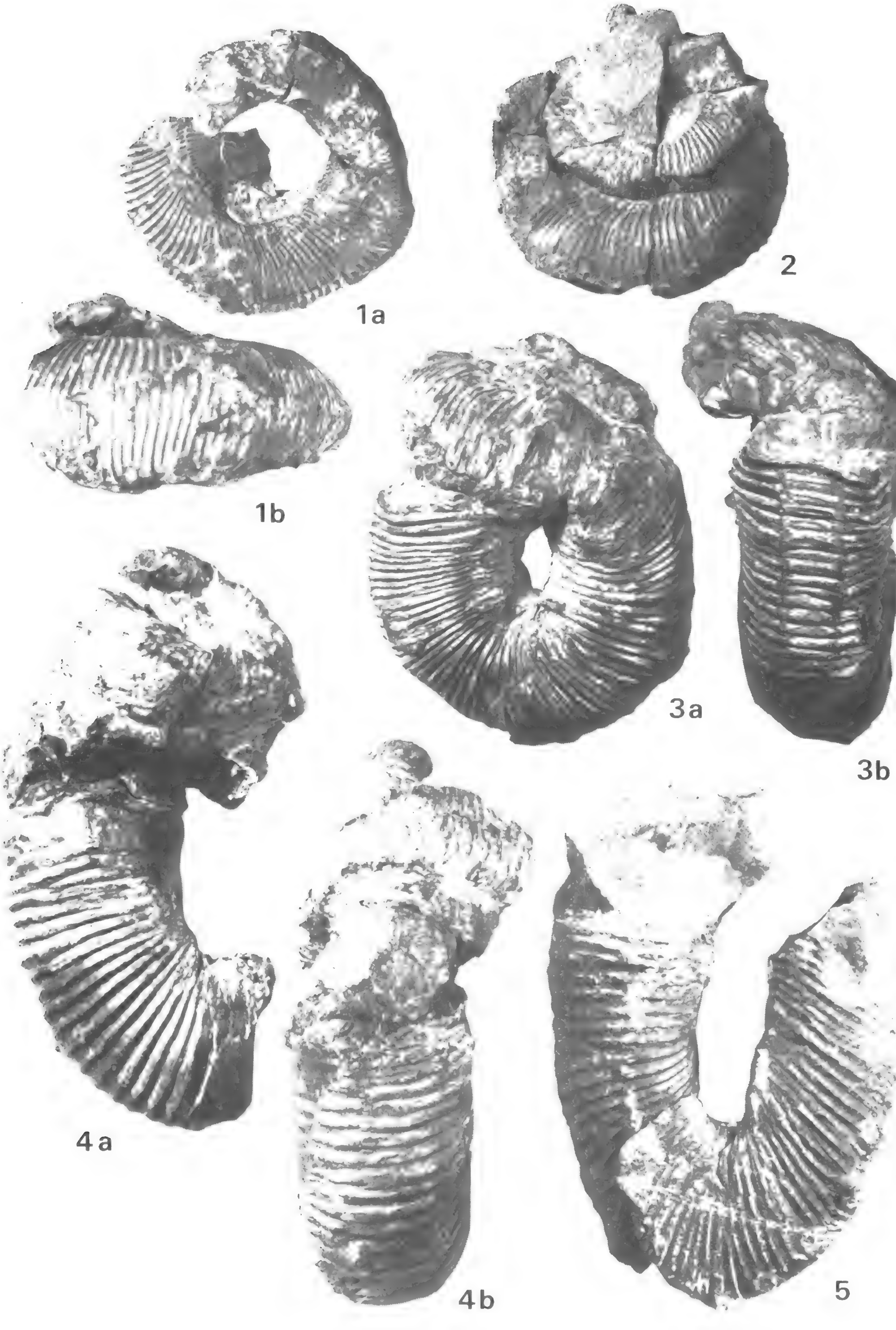
3

Explanation of Plate 16

Figs. 1–5. *Nostoceras hetonaiense* MATSUMOTO

1. MT136, part of spire. Apical (a) and lateral (b) views, × 1.
2. Upper view of TN81078, part of spire, × 1.
3. OMNH. M2209, fairly deformed shell. Two lateral views, × 1.
4. MT02, part of spire and last shaft of body chamber. Two lateral views, × 1.
5. TN81076, internal mould of body chamber, × 1.

All specimens from loc. Aw14 (Mitsugawa), Kita-ama Formation.


1a
1b
2
3a
3b
4a
4b
5

Explanation of Plate 17

Figs. 1–3. *Solenoceras* (*Solenoceras*) sp. cf. *S.* (*S.*) *texanum* (SHUMARD)

1 . OMNH.M2210, 2. TN820620 and 3. TN830514; all from loc. Aw2 (Minakuchi), upper part of Seidan Formation.

Ventral (1a) and lateral (1b, 2, 3) views, × 1 .

Fig. 4. *Solenoceras* (*Oxybeloceras*) sp. aff. *S.* (*O.*) *humei* (DOUVILLÉ)

Lateral view of OMNH.M2177-3, loc. Aw6 (Minato), "Minato Shale", Seidan Formation, × 1 .

Fig. 5. *Nostoceras hetonaiense* MATSUMOTO

MT193, fragmentary body chamber, loc. Aw14 (Mitsugawa), Kita-ama Formation, × 1 .

Fig. 6. *Nostoceras* sp. cf. *N. hetonaiense* MATSUMOTO

SN02, shell with poorly developed tubercles, loc. Aw12 (Chikusa), Kita-ama Formation.

Three lateral views, × 1 .

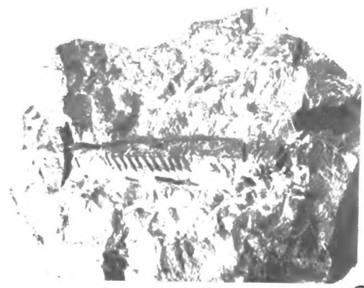
1a

1b

2

4

5



3

6a

6b

6c

Explanation of Plate 18

Figs. 1–2. *Pravitoceras sigmoidale* YABE

1. KI01, extremely large shell with the length of 365 mm, loc. Aw2 (Minakuchi), upper part of Seidan Formation. Lateral view, × 1/2.
2. OMNH. M2177-1, fairly well preserved specimen of normal size, loc. Aw6 (Minato), "Minato Shale", Seidan Formation, × 1/2.
   This is re-figured from MATSUMOTO *et al.* (1981b, pl. 22) for the comparison.

1

2

Explanation of Plate 1

Figs. 1-5. *Hypophylloceras* (*Neophylloceras*) *hetonaiense* MATSUMOTO

1 . GK. H6886, 2 . GK. H6884, 3 . GK. H6885 and 5 . GK. H6888; all from loc. Aw15 (Haraikawa), Shimonada Formation, × 1 .

4 . OMNH. M2208, loc. Awl (Kiba), "Minato Shale", Seidan Formation, × 1 .

Fig. 6. *Hypophylloceras* (*Neophylloceras*) sp. aff. *H.* (*N.*) *mikobokense* (COLLIGNON)

OMNH. M2190, fragmentary septate whorl, loc. Aw7 (Nagata), Seidan Formation. Lateral view (a) and natural whorl section (b), × 1 .

Fig. 7. *Pachydiscus* sp.

OMNH. M2189, internal mould, loc. Aw9 (Kemuri-jima), Kita-ama Formation, × 1 .